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DESIGN OF AN AMINE EXTRACTION DEMONSTRATION PLANT

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OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE NUCLEAR COMPANY
A Division of Union Carbide and Carbon Corporation
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DESIGN OF AN AMINE EXTRACTION DEMONSTRATION PLANT

1. INTRODUCTION

For several years a part of the raw materials program of the Oak Ridge National Laboratory has been concerned with the investigation and evaluation of different reagents to extract uranium from the aqueous solutions that are encountered in the processing of uranium ores. One of the processes that has resulted from these studies utilizes specific amines, dissolved in kerosene, to extract uranium from clarified leach liquors of the type derived by leaching uranium ores with sulfuric acid.[1,2,3] This process has been designated as the Amine Extraction Process.[4]

The amine extraction process has been extensively tested in the chemical laboratory and a process test facility. The final step prior to full-scale application is that of demonstrating the process in a complete large-scale plant. An estimate has been made of the cost of uranium recovery by this process in a plant designed to treat 200 tons of ore per day.[5] The recovery costs were estimated to be from $0.67 to $0.72 per lb of U_3O_8, depending on the composition of the ore. These costs start with the leached slurry and include all operating and amortization costs (no overhead) through product packaging.

This report presents the design of a demonstration plant to process clarified sulfate leach liquor at a rate equivalent to leaching 1,000 lb of ore per hr. The cost of installing it in the pilot plant facility in Grand Junction, Colorado (operated by National Lead Company), is estimated to be about $61,000. The cost of operating it is estimated to be about $140.00 per day.

A summary of the costs of installing the demonstration plant in an existing building are shown in Table 1.1. Only those items of equipment that comprise the extraction, stripping, uranium precipitation, and auxiliaries are included in the estimated installed cost. The design and selection of equipment were made so that the demonstration plant will serve as a prototype for a full-scale installation. In order to estimate the installed cost of the facility it was necessary to select specific items of equipment for which cost data were available. It is not intended to imply that equipment made by other manufacturers will not be equally suitable or, in some cases, better. The costs of operating the demonstration plant on a daily basis are summarized in Table 1.2. The equipment specifications and operating costs are given in Appendix A and B, respectively.

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TABLE 1.1 INSTALLED COST OF FACILITY

A.	Process Facilities	
	1. Installed equipment[1/]	$32,000
	2. Building[2/]	-
	3. Process piping (30% of A-1)	9,600
	4. Instrumentation (3% of A-1)	960
	5. Electrical installation (23.3 kw at $50/kw)[3/]	1,165
	6. Painting and scaffolding (2% of A-1)	640
	7. Footings and foundations (5% of A-1)	1,600
	Total Process Facilities	$45,965
B.	Engineering and Field Expense (10% of A)	4,597
C.	Contingency [10% of (A+B)]	5,056
D.	Contractor's fee and overhead [10% of (A+B+C)]	5,562
	Total Construction Cost	$61,180

1/ See Table 2.2 and Appendix A for details.

2/ Installed in existing building.

3/ See Appendix B for details.

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TABLE 1.2. OPERATING COST OF FACILITY

Item	Cost Per Day
Labor	
Operating[1]	$ 83.09
Maintenance[2]	6.80
Supplies	
Operating[3]	7.39
Maintenance[4]	8.50
Utilities	
Electricity[5]	2.13
Steam[6]	1.62
Total Operating Costs	$109.53
Amortization[7]	33.99
Total	$143.52

1/ See Appendix B.

2/ 4% of Total Construction Cost per 360-day year.

3/ See Appendix B.

4/ 5% of Total Construction Cost per 360-day year.

5/ 194 kwh at $0.011 per kwh. See Appendix B.

6/ 1,803 lb at $0.90 per M lb.

7/ 20% of Total Construction Cost per 360-day year.

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2. PLANT DESIGN

2.1 Description of the Process

Clarified leach liquor is passed through four mixer-settler units countercurrent to the organic phase which extracts essentially all of the uranium from the liquor. The organic phase is a 0.1 molar solution of Rohm and Haas Amine 9D-178* (formerly EB-765-2) dissolved in kerosene. The raffinate (barren leach liquor) is pumped to the waste disposal pond.

The organic extract from the extraction operation is contacted countercurrently with a 1 molar aqueous solution of sodium chloride in three mixer-settler units to transfer (strip) uranium from the organic to the aqueous phase. The loaded strip solution is pumped to the precipitation unit and the barren organic is pumped back to the extraction operation to start another cycle. A secondary stripping operation is employed when the leach liquor contains an appreciable quantity of molybdenum. In this operation molybdenum is stripped from the organic phase by contacting it with a 10% sodium carbonate solution.

Uranium is precipitated from the loaded strip solution by the addition of ammonia. The slurry is filtered and the washed cake is then calcined and packaged for shipment. The filtrate and wash solution are discarded to waste. A schematic flow diagram of the process is shown in Fig. 2.1.

The design of the demonstration plant is presented in the following sections.

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*For information on the use of other amines see ORNL-1922 (K. B. Brown, et al., Further Studies of Amines as Extractants for Uranium from Acid Sulfate Solution).

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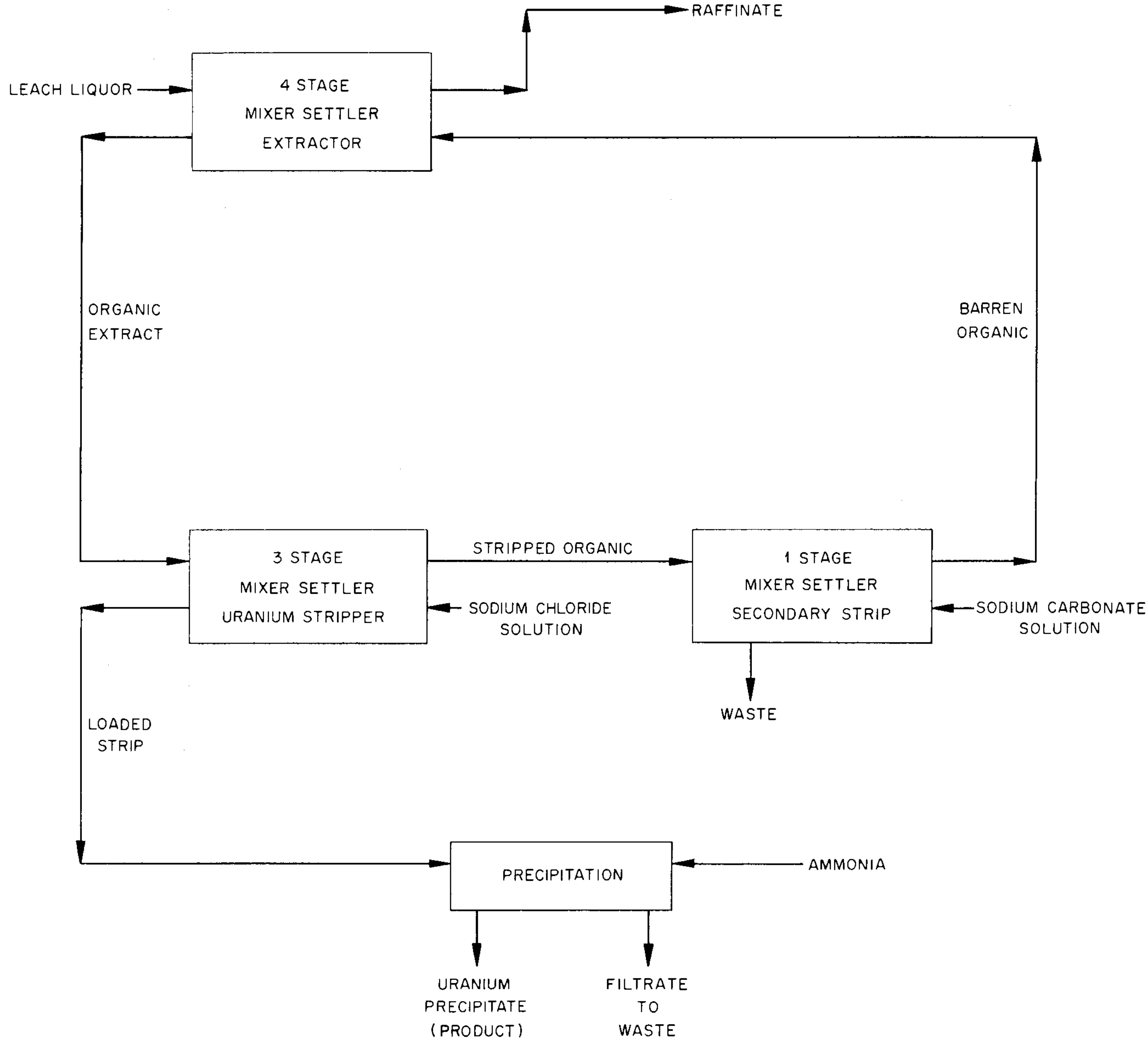

Fig. 2.1. Schematic Flow Diagram.

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2.2 Scope of the Process Equipment

The design and equipment specifications start with three clarified leach liquor storage tanks from which the feed is pumped to the extraction section and end with the uranium precipitation tanks. It is assumed that facilities are available for: (1) producing approximately 2,000 lbs per hr of clarified leach liquor from a leach slurry containing about 60 percent solids at an ore feed rate of 1,000 lbs per hr; and (2) filtering and washing the uranium precipitate and calcining it for packaging and shipping.

2.3 Criteria

The criteria employed as the basis for the demonstration plant design are listed in Table 2.1. The source of these criteria were: (1) assumptions, (2) process testing experience, and (3) recommendations contained in "Suggested Procedure for Economic Evaluation for Uranium Recovery Plants," Grand Junction Operations Office, Division of Raw Materials, AEC.

Although an over-all recovery of greater than 99.8% of the U_3O_8 in the clarified leach liquor was consistently obtained in the process testing work, a value of 99.5% was assumed for the demonstration plant to provide a reasonable factor of safety.

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TABLE 2.1 DESIGN CRITERIA

General:	
Location of plant[1]	Grand Junction, Colorado.
Capacity of plant[1]	1,000 lb of ore per hr.
Assay of ore[1]	0.3% U_3O_8 by wt.
Clarified liquor rate[2]	Twice the gross wt of ore.
U_3O_8 in liquor[2]	94% of U_3O_8 in the ore.
U_3O_8 in product[2]	99.5% of U_3O_8 in the liquor.
Extraction:	
Organic extractant[3]	Rohm and Haas amine 9D-178.
Organic diluent[3]	Kerosene.
Concentration of amine in diluent[3]	0.1 molar.
Loading of organic extract[3]	4.24 grams U_3O_8 per liter.
Type of extractor[3]	4-stage mixer-settler.
Residence time mixer[3]	0.33 minutes.
Residence time in settler[3]	3.65 minutes (interstage). 8.01 minutes (raffinate).
Stripping:	
Stripping agent[3]	1 molar NaCl in 0.05 molar H_2SO_4 soln.
Theoretical stripping requirement	1 mole NaCl per mole amine.
Actual strip usage[3]	1.5 moles NaCl per mole amine.
Type of stripper[3]	3-stage mixer-settler.
Residence time in mixer[3]	1.2 minutes.
Residence time in settler[3]	12.4 minutes.
Precipitation:	
Precipitant	Ammonia (anhydrous).
Ammonia requirement[3]	4.5 moles ammonia per mole uranium.
Secondary Strip:	
Secondary stripping agent[3]	Sodium carbonate.
Carbonate concentration[2]	10% solution.
Theoretical CO_3 requirement	0.5 mole CO_3 per mole amine.
Actual CO_3 usage[3]	105% of theoretical.
Type of secondary stripper[3]	Single-stage mixer-settler.
Rate of Loss of Organic Phase:	
Entrainment[3]	0.25 ml organic per l. aq.
Solubility of amine in aq[3]	32 ppm.
Miscellaneous spills and samples[2]	100 gal per month.

1/ "Suggested Procedure for Economic Evaluation for Uranium Recovery Plants," Grand Junction Operations Office, AEC.
2/ Assumed.
3/ Based [redacted]boratory and process testing data.

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2.4 Process Considerations

The amine extraction process utilizes specific amines dissolved in an organic carrier to separate uranium by solvent extraction techniques from most of the potential contaminants in the head liquor. A brief discussion of the chemical technology that characterizes the process is given in the following paragraphs.

2.4.1 Extraction

The Amine Extraction Agent. The extraction agent considered here is a secondary amine*, 9D-178, which would be obtainable from Rohm and Haas Company, Philadelphia, in commercial quantities at a reasonable price. This particular compound was selected for initial operation of the demonstration plant since it has received the greatest share of attention in process development studies conducted thus far. Although good extraction performance may be obtained with this reagent, equivalent or in some cases superior performance has been shown by other potentially available amine reagents.** It is not intended to imply that this particular amine is necessarily the best choice for a general, or any specific application, of the amine extraction process. However, the use of a different amine would not involve any changes in the plant equipment.

With one possible exception, the Rohm and Haas 9D-178 amine and its salts that form in the extraction and stripping operation are readily soluble in kerosene. The exception is an amine-molybdenum-pentavalent vanadium complex that forms in the extraction operation under certain conditions that will be discussed subsequently.*** The stability of the amine during continuous process use was demonstrated through 200 extraction and stripping cycles. The total loss of amine was about 41 ppm based on raffinate, of which 32 ppm were loss of amine from the organic phase and 9 ppm were lost in the organic phase entrained in the raffinate. Since direct laboratory measurements of solubility losses of this amine (from kerosene)

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*One of the alkyl groups is a saturated, highly branched alkyl chain in which a tertiary carbon is attached to the nitrogen while the other alkyl is a branched dodecenyl group.

**See ORNL-1734, ORNL-1922, and ORNL-1959.

***This exception would not apply to several other amine reagents.

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to aqueous solutions of about the same composition have ranged from 24 to 31 ppm, the amount of amine lost by chemical degradation was indicated to be unimportantly low.

Selectivity and Control. The results of extensive tests[1,2,3,4] have shown: (1) that other than uranium only molybdenum, pentavalent vanadium, and ferric iron are extracted to an appreciable extent at any point in the extraction operation from head liquor compositions that cover the range of most domestic ores, (2) that the extraction of both vanadium and iron can be reduced to the point where they are not significant contaminants of the product by maintaining the proper uranium loading, (3) that molybdenum is extracted as readily as is uranium; however, most of it is separated from the uranium in the stripping and uranium precipitation, filtration and product cake washing operations.

To minimize the consumption of stripping chemicals and depress the extraction of contaminating ions, it is important to maintain as high a concentration of uranium in the extract as can conveniently be obtained. This is accomplished by employing an aqueous to organic phase ratio such that, with a concentration of amine in the organic phase of 0.10 to 0.11 molar, the uranium content will be about 3.6 grams per liter. To facilitate operation and control of the extraction and stripping operation, the design provides for sufficient holdup volume for the clarified head liquor so that an analysis of the liquor will be available prior to its use.

pH of the Head Liquor. With pH values of the head liquor ranging from 0.5 to 1.5, satisfactory extraction of uranium was obtained for all head liquor compositions employed in the tests under the conditions of uranium loading in the organic phase described previously.[4]

2.4.2 Stripping

Uranium Stripping. The loaded organic phase can be stripped of its uranium content by a variety of stripping agents (OH^-, $CO_3^=$, Cl^-, and NO_3^-). Sodium chloride was selected as the stripping agent because of its low cost. With this agent a multistage stripping operation using countercurrent phase flows is necessary just as it is in the extraction operation. Laboratory and process testing studies have shown that, with a flow rate of 1 molar salt solution (0.05 M in H_2SO_4) that is 50% in excess of the theoretical requirement (1 M NaCl per mole of amine), the equilibrium between the uranium in the aqueous salt solution and that in the stripped organic phase is such that a small quantity of uranium (about

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6 ppm) remains in the organic phase and is recycled to the extraction operation. It was also established that most of the molybdenum remained in the organic phase. The stripping of organic extracts which contain an appreciable quantity of molybdenum is described in the section following.

Molybdenum Stripping. Molybdenum will probably be present in small amounts in leach liquors from many of the Colorado Plateau ores and in significant amounts in some, such as Arrowhead and Marysvale ores. It is readily extracted by the amine and it can be stripped from the organic phase by sodium carbonate but not by sodium chloride.

When processing liquors that contain a relatively high concentration of molybdenum as well as some pentavalent vanadium, an amine-molybdenum-vanadium(V) complex forms which has limited solubility in kerosene*. In this case, Amsco G (American Mineral Spirits Co.) is used as the organic solvent in place of kerosene and the organic phase is passed through an alkaline**, sodium carbonate, strip to prevent a buildup of molybdenum in the organic phase to the detriment of the uranium extraction efficiency. A secondary stripping section has been provided in the design which is shown in dotted lines on Fig. 2.2.

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*Under similar conditions, with several other amines in kerosene, no precipitate was formed, e.g., C&C 16F27, di(tridecyl P), tri(n-octyl), N-benzyl 1-(3-ethylpentyl)-4-ethyloctyl, and dodecenyl Primene JM amines.

**Laboratory process development studies have shown that calcium hydroxide also is an effective stripping agent. It has not been tested in a continuous countercurrent test array.

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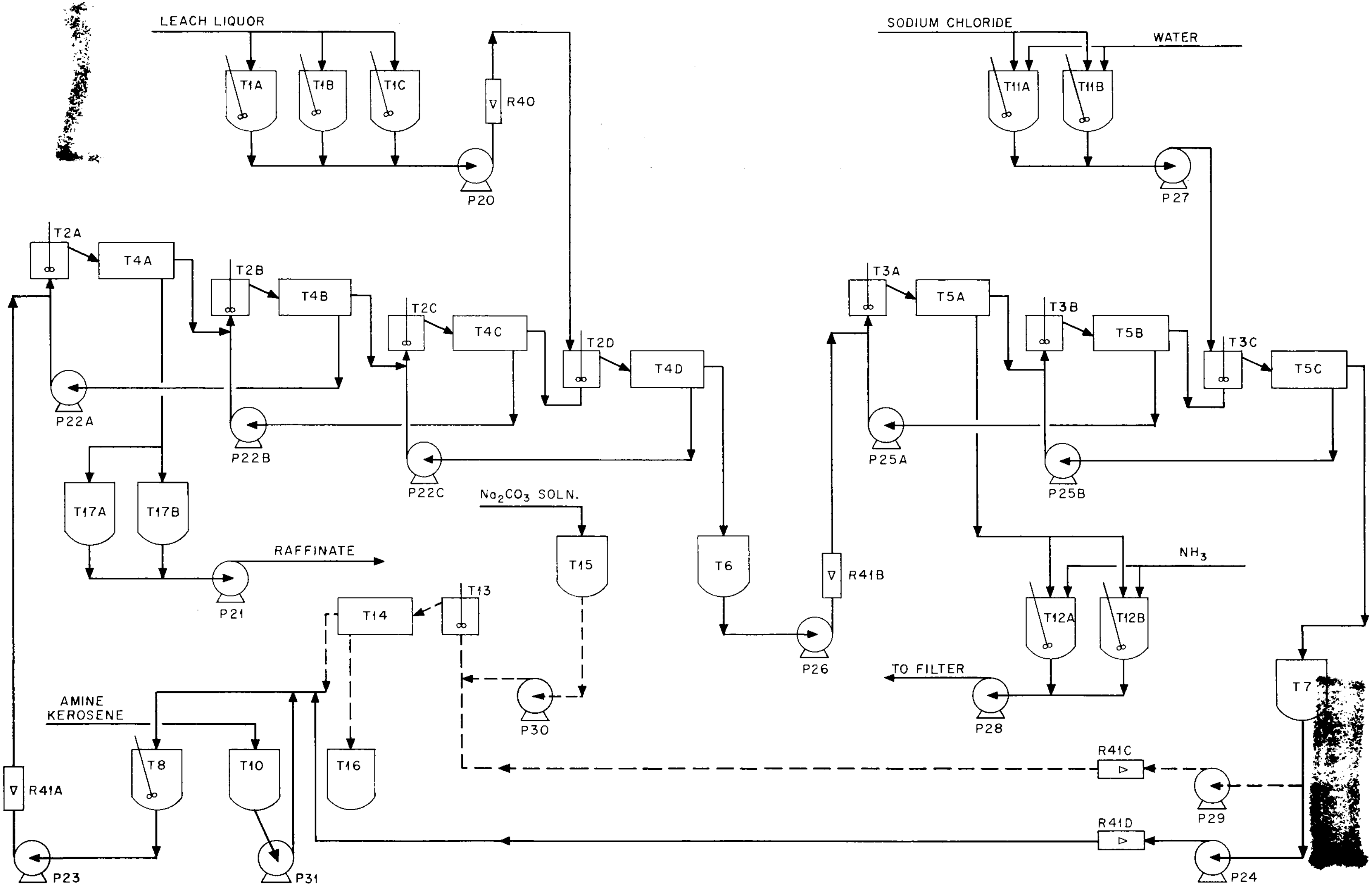

Fig. 2.2. Engineering Flow Diagram.

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2.5 Material Balance

The volumetric and mass flow rates for the main pilot plant streams are shown in Fig. 2.3 for a 24-hr period.

2.6 Equipment Design and Specifications

One of the advantages of the amine extraction process is that it employs conventional equipment that is both mechanically and operationally simple. The pilot plant design starts with three head tanks which receive and hold head liquor from the clarification operation. Each tank holds an 8-hr supply of feed to the extraction section which has been mixed to a uniform composition and analyzed prior to its use. The flow rates of organic extractant and strip solution are based on the composition of the head liquor.

The use of standard baffled tanks as mixers makes it possible to scale up the results of pilot plant experimentation to large equipment by application of the principles of fluid mechanics and similitude.[6,7,8,9] These mixers have been tested in process testing studies with combined flow rates of aqueous and organic up to 5 gpm. The settlers are shallow tanks which contain a baffle to prevent short circuiting of the fluids, a distributor plate to prevent jetting of the mixed phases inlet stream, and a weir to provide a sufficient depth of organic phase to prevent inclusion of aqueous phase by vortex action. Details of the mixers and settlers are given in Appendix A (Figs. A-1 and A-2). The remaining equipment consists of tanks, pumps, and flow indicators.

The equipment layout is shown in Fig. 2.2. A listing of the important items of equipment is given in Table 2.2. To estimate the installed cost of the facility it was necessary to select specific items of equipment (Appendix A) for which the cost data were available and these costs are also shown in Table 2.2. It is obvious that equipment made by a number of different manufacturers meet the specifications given in Appendix A; therefore, the selection of specific examples should not imply partiality toward the equipment selected for pricing, or its manufacturer.

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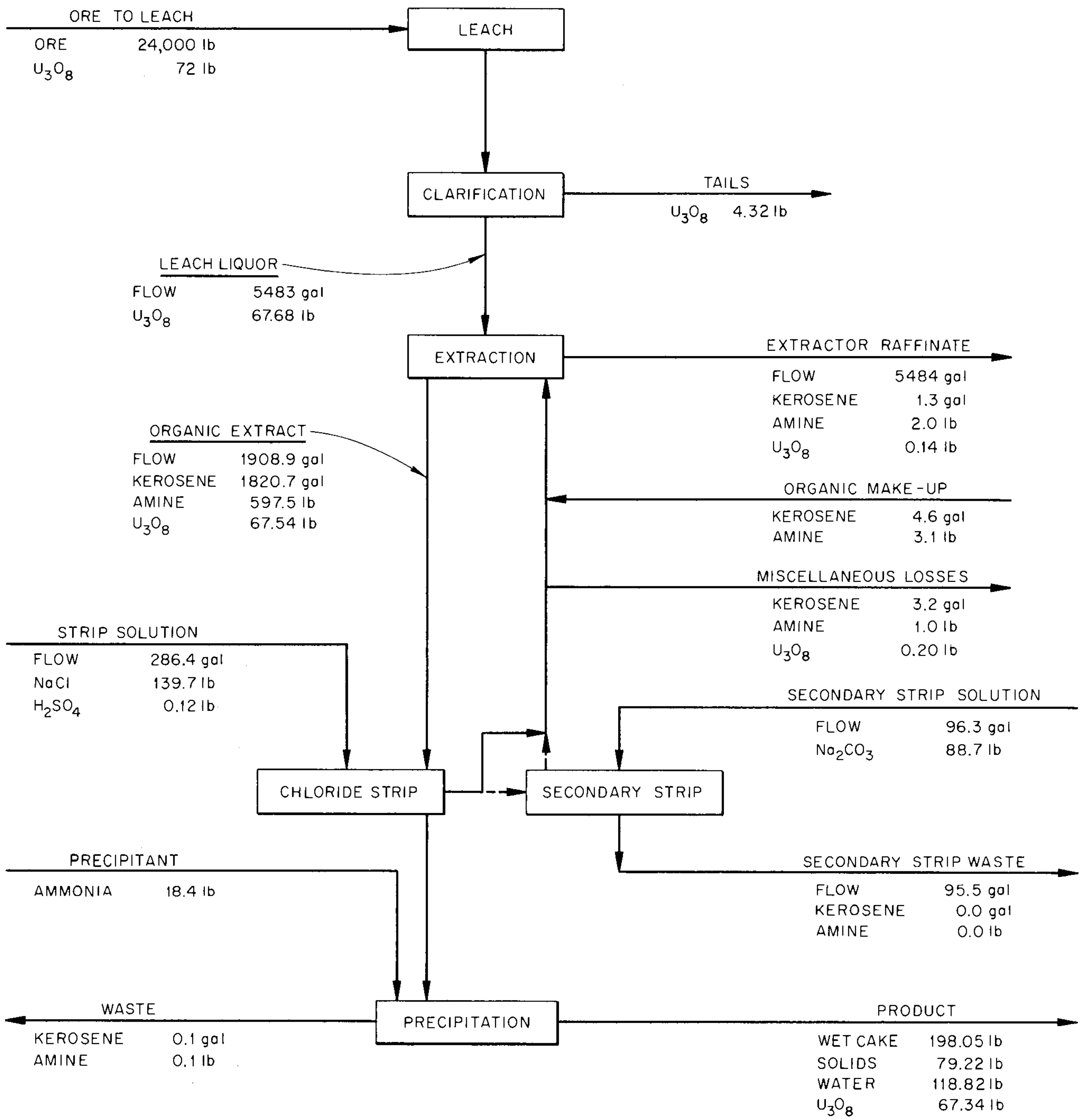

Fig. 2.3 Material Flow Diagram (Basis - One 24 Hour Day)

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TABLE 2.2 EQUIPMENT

Item No.	Quantity	Equipment	Installed Cost Each	Total Installed Cost
T-1	3	Feed tanks, wood, 2,278 gal	$1,800	$ 5,400
T-2	4	Extractor mixer, plastic lined steel, 1.7 gal	810	3,240
T-3	3	Stripper mixer, plastic lined steel, 1.7 gal	810	2,430
T-4	3	Extractor settler, plastic lined steel, 18.7 gal	550	1,650
T-4	1	Extractor settler, plastic lined steel, 41.1 gal	615	615
T-5	3	Stripper settler, plastic lined steel, 18.7 gal	550	1,650
T-6	1	Organic head tank, plastic lined steel, 43 gal	385	385
T-7	1	Organic head tank, plastic lined steel, 31 gal	355	355
T-8	1	Organic storage tank, plastic lined steel, 113 gal	1,450	1,450
T-10	1	Organic phase make-up tank, steel, 100 gal	290	290
T-11	2	Strip make-up tank, wood, 365 gal	900	1,800
T-12	2	Precipitation tanks, wood, 365 gal	900	1,800
T-13	1	Secondary strip mixer, plastic lined steel, 1.7 gal	810	810
T-14	1	Secondary strip settler, plastic lined steel, 18.7 gal	550	550
T-15	1	Secondary strip feed tank	120	120
T-16	1	Spent secondary strip receiver	120	120
T-17	2	Raffinate tank, plastic lined steel, 2,000 gal	1,715	3,430
P-20	2	Leach liquor pump, feed	195	390
P-21	2	Leach liquor pump, raffinate	670	1,340
P-22	4	Leach liquor pump, interstage	195	780
P-23	2	Organic pump, to extractor	185	370
P-24	2	Organic pump, barren	185	370
P-25	3	Strip pump, interstage	235	705
P-26	1	Organic pump, loaded	185	185
P-27	2	Strip pump, feed	235	470
P-28	1	Precipitate pump, to filter	195	195
P-29	1	Barren organic pump to secondary strip	185	185
P-30	1	Secondary strip pump	138	138
P-31	1	Organic pump, make-up	277	277
R-40	1	Aqueous flowmeter extractor	140	140
R-41	4	Organic flowmeter	90	360
				$32,000

[redacted] [redacted]

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APPENDIX A. EQUIPMENT SPECIFICATIONS

EXTRACTION SECTION

Clarified leach liquor from any one of the three feed tanks (see Fig. 2.2) for which an analysis is known is pumped to the extract end of the 4-unit mixer-settler array through which it is passed countercurrent to the organic phase. The organic phase is transported through the mixer-settlers by gravity head while the aqueous phase is pumped from the settler to the next mixer in line. The loaded organic extract flows by gravity to an organic holdup tank before being pumped to the uranium stripping section and the raffinate is pumped to waste.

Tank T-1 (A, B, and C)

Duty:

To act as receiver for head liquor from the clarification circuit, hold 8 hours' supply of head liquor (1830 gals) that is mixed to a uniform composition and sampled, serve as a feed tank for the extraction section.

Selection:

Tank

No. required:	3
Capacity:	2,278 gals (8-ft diam, 7 ft deep)
Material:	wood

Agitator drive

No. required:	3
Power:	5 hp portable
Speed:	120 rpm
Shaft material:	316 S.S.

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Impeller

No. required: 3

Type: 6-blade turbine or equivalent

Size: 1-ft diam

Material: 316 S.S.

Installed cost: $1,800 each (Denver Equip. Co.)

Mixer Tank T-2 (A,B,C, and D)

Duty:

To mix aqueous leach liquor and organic phase.

Selection: (see Fig. A-1)

Tank

No. required: 4

Tank diam: 8 in.

Effective depth: 8 in.

Over-all depth: 14 in.

Material: Plastic lined steel

Agitator drive

No. required: 4

Power: 1/4 hp

Speed: 400 rpm

Shaft material: 316 S.S. coated with plastic

Impeller (see Fig. A-1)

No. required: 4

Type: 4-blade turbine

Size: 4-in. diam

Material: 316 S.S. coated with plastic

Installed cost: $810 each (United States Stoneware Co.)

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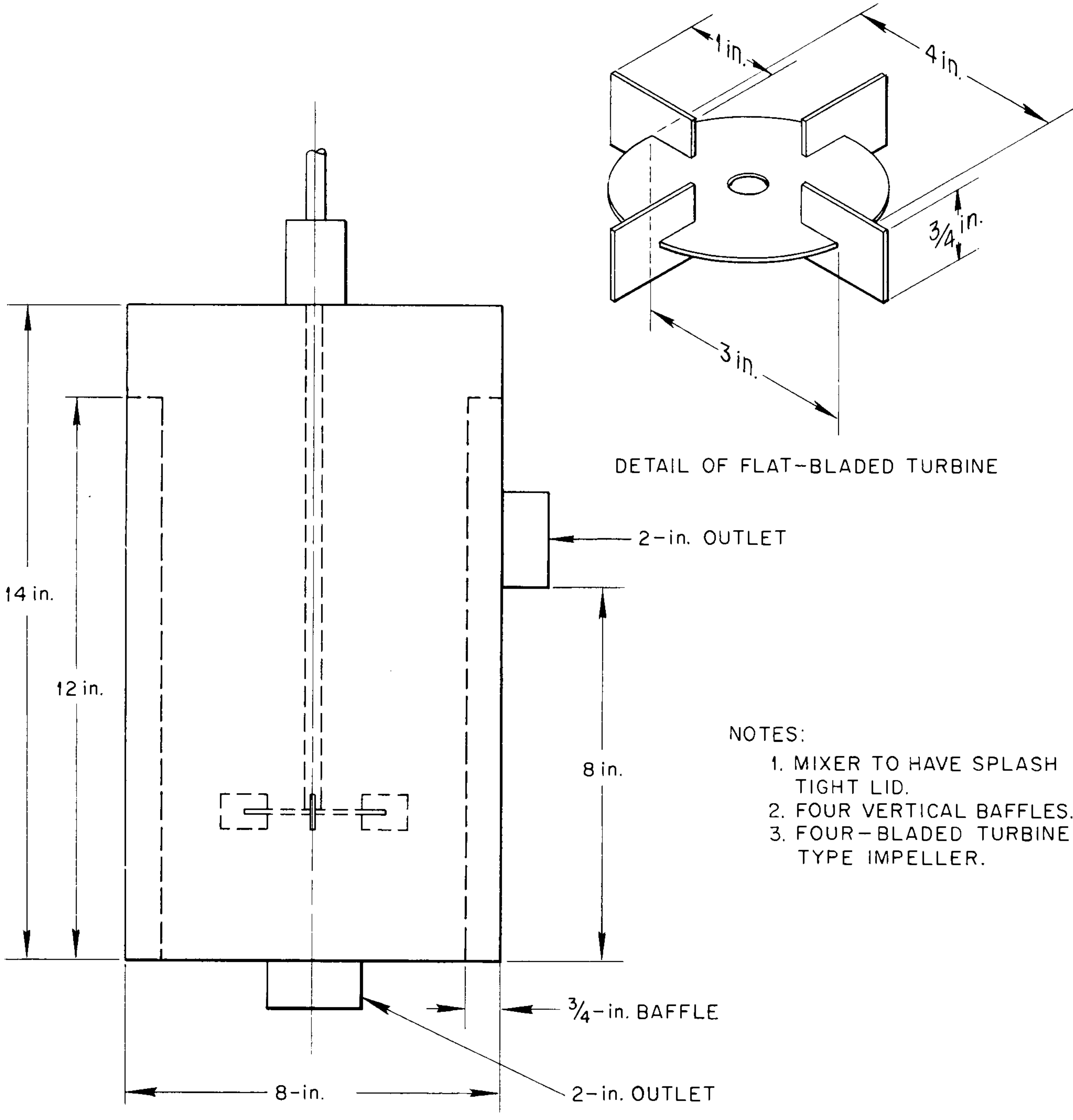

Fig. A.1. Extractor Mixer, T-2.

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Settler Tank T-4 (A,B,C, and D)

Duty:

To receive mixed phases from mix tanks (T-2) and provide holdup time for the two phases to separate.

Selection: (see Fig. A-2)

No. required: 4

Diameter: Interstage settler (B,C, and D) - 2.5 ft
Raffinate settler (A) - 3.0 ft

Effective depth: 12 in.

Over-all depth: 18 in.

Material: Plastic lined steel

Installed cost:

Interstage settler - $550 each (United States Stoneware Co.)
Raffinate settler - $615 each (United States Stoneware Co.)

Raffinate Tank T-17 (A and B)

Duty:

To receive raffinate and provide holdup time to permit final recovery of organic phase.

Selection:

No. required 2

Capacity: 2,000 gal

Material: Plastic lined steel

Installed cost: $1,715 each (United States Stoneware Co.)

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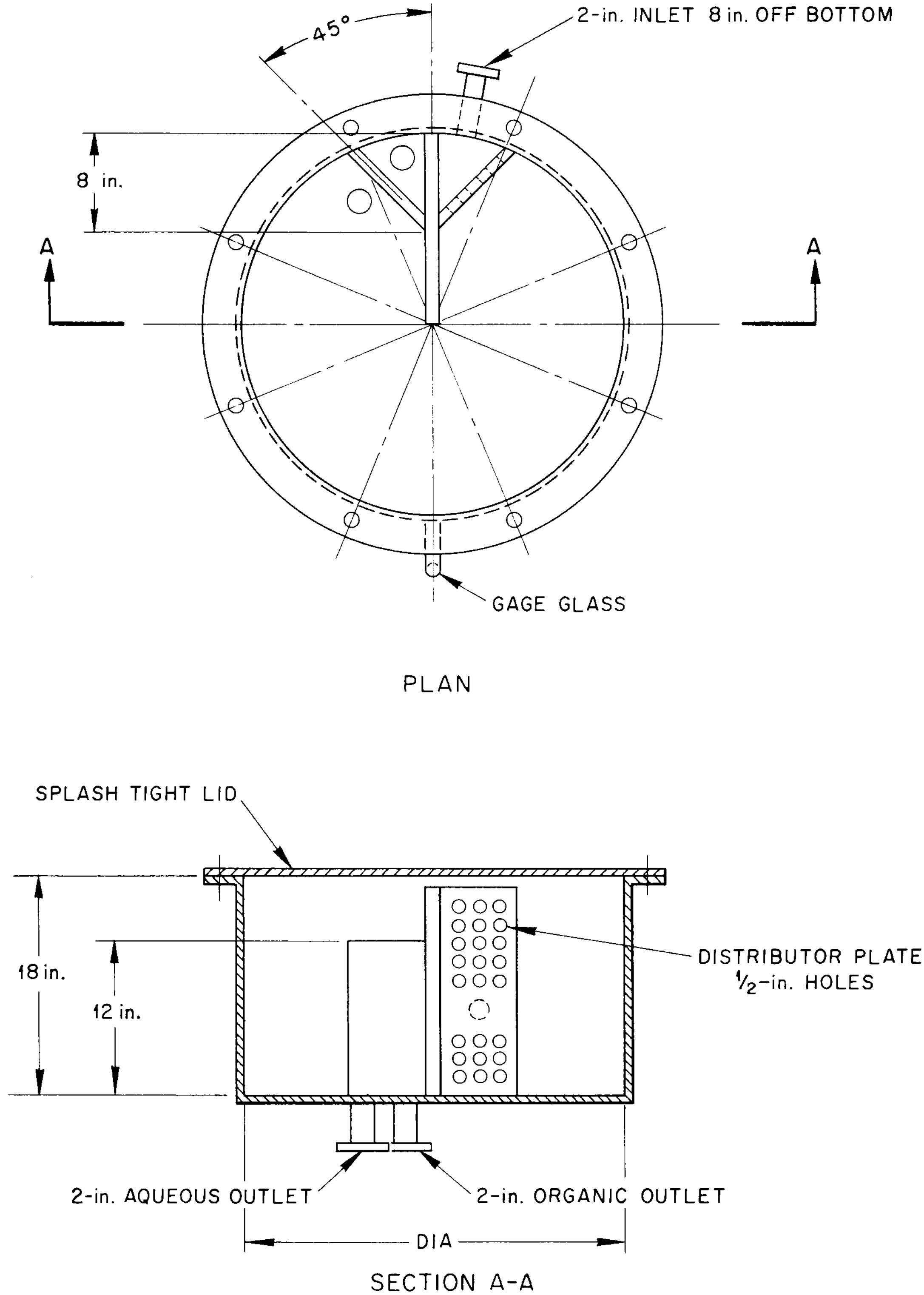

TANK	DIAMETER
INTERSTAGE SETTLER	2.5 ft
RAFFINATE SETTLER	3 ft

Fig. A.2. Settler.

[redacted] [redacted]

Feed Pump P-20

Duty:

To pump 3.81 gpm leach liquor from feed tanks (T-1) to extractor mixer (T-2, D).

Selection:

No. required: 2 (one spare)

*Make: Eastern Industries, Inc.

*Model: F

*Capacity: 0 to 5 gpm

*Head: 11 to 35 ft

*Speed: 3,450 rpm

*Motor rating: 1/3 hp

Material: 316 S.S.

Installed cost: $195 each.

Raffinate Pump P-21

Duty:

To pump contents of raffinate storage tank T-17 to waste disposal in one hour (30.5 gpm).

Selection:

No. required: 2 (one spare)

*Make: Jabsco Pump Co.

*Model: 340

*Capacity: 32 to 40 gpm

*Speed: variable

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*For cost estimating purposes only.

[redacted]

[redacted] [redacted]

*Motor rating: 1-1/2 hp

Material: rubber or plastic lined

Installed cost: $670 each.

Extractor Interstage Pump P-22 (A,B, and C)

Duty:

To pump 3.81 gpm aqueous phase from settler (T-4 series) to the next mixer in line (T-2 series).

Selection:

No. required: 4 (one spare)

*Make: Eastern Industries, Inc.

*Model: F

*Capacity: 0 to 5 gpm

*Head: 11 - 35 ft

*Speed: 3,450 rpm

*Motor rating: 1/3 hp

Material: 316 S.S.

Installed cost: $195 each

Rotameter R-40

Duty:

To indicate flow rate of aqueous phase to extraction system (3.81 gpm).

Selection:

No. required: 1

*Make: Fisher and Porter Co.

*Size: 8 (1.7 gpm to 17.2 gpm)

Installed cost: $140 each.

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*For cost estimating purposes only.

[redacted]

[redacted]

STRIPPING SECTION

The loaded organic extract is pumped to the three-unit mixer-settler array through which it passes countercurrent to an aqueous sodium chloride stripping solution. The organic phase passes through the mixer-settlers by gravity head while the aqueous phase is pumped successively from the make-up tanks and from each settler to the next mixer in line. The stripped organic phase flows by gravity to an organic holdup tank before being pumped either to the storage tanks and the extraction section or to the secondary stripping section.

The loaded aqueous strip flows by gravity from the last settler to the precipitation section.

Mixer T-3 (A,B, and C)

Duty:

To mix loaded organic extract and aqueous strip solution.

Selection: (Identical to mixer tank T-2)

Tank

- No. required: 3
- Tank diameter: 8 in.
- Effective depth: 8 in.
- Over-all depth: 14 in.
- Material: Plastic lined steel

Agitator drive

- No. required: 3
- Power: 1/4 hp
- Speed: 400 rpm
- Shaft material: 316 S.S. coated with plastic

[redacted]

[redacted] [redacted]

Impeller

No. required: 3

Type: 4-blade turbine type

Size: 4-in. diam

Material: 316 S.S. coated with plastic

Installed cost: $810 each (United States Stoneware Co.)

Settler Tank T-5 (A,B, and C)

Duty:

To receive mixed phases from mix tanks (T-4) and provide holdup time for the two phases to separate.

Selection: (Identical to Interstage Settler Tank T-4 B,C, and D)

No. required: 3

Diameter: 2.5 ft

Effective depth: 12 in.

Over-all depth: 18 in.

Material: Plastic lined steel

Installed cost: $550 each (United States Stoneware Co.)

Strip Make-up Tank T-11 (A and B)

Duty:

For batchwise preparation of aqueous strip solution and to serve as feed tank for the aqueous strip flow to the stripping section. Should have capacity equal to one day's flow (284 gal per day).

[redacted]

[redacted]

Selection:

Tank

No. required: 2

Capacity: 365 gal (4-ft diameter, 5 ft deep)

Material: wood

Agitator drive

No. required: 2

Power: 1-1/2 hp portable

Speed: 180 rpm

Shaft material: 316 S.S. covered with plastic

Impeller

No. required: 2

Type: 6-bladed turbine type or equivalent

Size: 12 in.

Material: 316 S.S. covered with plastic

Installed cost: $900 each (Denver Equipment Co.)

Strip Solution Interstage Pump P-25 (A and B)

Duty:

To pump 0.20 gpm aqueous strip phase from settler (T-5 series) to the next mixer in line (T-3 series).

Selection:

No. required: 3 (one spare)

*Make: Sigmamotor, Inc.

*Model: T-6

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*For cost estimating purposes only.

[redacted]

[redacted]

*Capacity:	0.08 to 0.50 gpm
*Speed:	Variable
*Motor rating:	1/6 hp
Material:	Tygon

Installed cost: $235 each

Strip Feed Pump P-27

Duty:

To pump 0.20 gpm aqueous strip solution from feed tank (T-11) to stripper mixer (T-3C).

Selection:

No. required:	2 (one spare)
*Make:	Sigmamotor, Inc.
*Model:	T-6
*Capacity:	0.08 to 0.50 gpm
*Speed:	Variable
*Motor rating:	1/6 hp
Material:	Tygon

Installed cost: $235 each

*For cost estimating purposes only.

[redacted]

[redacted] [redacted]

ORGANIC SECTION

Holdup is provided for the loaded organic extract between the extraction and the stripping sections. Holdup is also provided for the stripped organic between the stripping and extraction sections. In addition, an agitated holdup tank is provided so that the organic phase may be analyzed and fortified to maintain the amine content at the desired concentration.

These tanks permit handling of the organic phase with minimum losses and assure continuity of flow around the organic loop without interruptions.

<u>Organic Head Tank T-6</u>

Duty:

To act as receiver for loaded organic extract from extraction section, to hold 10-min supply of loaded organic extract (13 gals), to provide volume for draining organic from extraction section on shutdown (26 gals), to provide for secondary drain-off of separated aqueous phase to further reduce entrainment of aqueous from the extraction to the stripping sections, to act as feed tank from extraction to stripping sections.

Selection:

No. required: 1

Diameter: 14 in.

Normal liquid depth: 13 in.

Total depth: 60 in.

Capacity: 43 gals

Material: Plastic lined steel

Installed cost: $385 (United States Stoneware Co.)

[redacted]

[redacted] [redacted]

Organic Head Tank T-7

Duty:

To act as receiver for stripped organic from stripping section, to hold 10-min supply of stripped organic (13 gals), to provide volume for draining organic from stripping section on shutdown (15 gals), to provide for secondary drainoff of separated aqueous phase to further reduce entrainment of aqueous from U stripper section to secondary strip section (or extraction section), to act as feed tank from stripping to extraction and/or secondary strip section as required.

Selection:

No. required: 1

Diameter: 12 in.

Normal liquid depth: 26 in.

Total depth: 60 in.

Capacity: 31 gals

Material: Plastic lined steel

Installed cost: $355 (United States Stoneware Co.)

Organic Storage Tank T-8

Duty:

To act as receiver for organic phase, hold volume equivalent to organic phase capacity in all systems (67 gals) plus 10-min supply of organic (13 gals), serve as a feed tank for the extraction system.

Selection:

Tank

No. required: 1

Capacity: 113 gal (30-in. diam, 36 in. deep)

Material: Plastic lined steel

[redacted] [redacted]

[redacted] [redacted]

Agitator drive

No. required: 1

Power: 1 hp

Speed: 400 rpm

Shaft material: 316 S.S. covered with plastic

Impeller

No. required: 1

Type: 6-blade turbine type or equivalent

Size: 6-in. diameter

Material: 316 S.S. covered with plastic

Installed cost: $1,450 each (United States Stoneware Co.)

Organic Preparation Tank T-10

Duty:

To make up concentrated solution of amine in kerosene (0.6 molar) to add to organic phase for make-up of amine losses.

Selection:

Tank

No. required: 1

Capacity: 10 gals

Material: 316 S.S.

Agitator drive

No. required: 1

Power: 1/4 hp

Speed: 400 rpm

Shaft material: 316 S.S.

[redacted]

[redacted] [redacted]

Impeller:

No. required:	1
Type:	6-bladed turbine type or equivalent
Size:	3-in. diam
Material:	316 S.S.

Installed cost: $290 each (Alsop Engineering Corp.)

Organic Phase Pump P-23

Duty:

To pump 1.32 gpm organic phase from head tank (T-8) to extraction section (T-2A).

Selection:

No. required:	2 (one spare)
*Make:	Eastern Industries, Inc.
*Model:	D-11
*Capacity:	0-2 gpm
*Head:	30-37 ft
*Speed:	3,450 rpm
*Motor rating	1/8 hp
Material:	316 S.S.

Installed cost: $185 each

Organic Pump P-24

Duty:

To pump up to 1.32 gpm organic phase from head tank (T-7) to storage tank (T-8).

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*For cost [redacted]timating purposes only.

[redacted] [redacted]

[redacted] [redacted]

Selection:

No. required: 2 (one spare)

*Make: Eastern Industries, Inc.

*Model: D-11

*Capacity: 0-2 gpm

*Head: 30-37 ft

*Speed: 3,450 rpm

*Motor rating: 1/8 hp

Material: 316 S.S.

Installed cost: $185 each

Organic Pump P-26

Duty:

To pump 1.32 gpm organic phase from head tank (T-6) to stripping section (T-3A).

Selection:

No. required: 1

*Make: Eastern Industries, Inc.

*Model: D-11

*Capacity: 0-2 gpm

*Head: 30-37 ft

*Speed: 3,450 rpm

*Motor rating: 1/8 hp

Material: 316 S.S.

Installed cost: $185 each

*For cost estimating purposes only.

[redacted]

[redacted] [redacted]

Organic Pump P-29

Duty:

To pump up to 1.32 gpm organic phase from head tank (T-7) to secondary stripping section (T-13) mixer.

Selection:

No. required:	1
*Make:	Eastern Industries, Inc.
*Model:	D-11
*Capacity:	0-2 gpm
*Head:	30-37 ft
*Speed:	3,450 rpm
*Motor rating:	1/8 hp
Material:	316 S.S.

Installed cost: $185 each

Organic Pump P-31

Duty:

To feed make-up organic from T-10 to T-8 in one hour (0.083 gpm)

Selection:

No. required:	4 tubes (2 spare)
*Make:	Brosites Machine Co.
*Model:	Six-in-one proportioning pump Model "O"
*Head:	8 ft

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*For cost estimating purposes only.

[redacted] [redacted]

[redacted] [redacted]

*Motor rating: 1/20 hp

Material: Rubber

Installed cost: $415 each

Allocated cost: $277 (see pump P-30)

Rotameter R-41 (A,B,C, and D)

Duty:

To indicate flow rate of organic phase (1.32 gpm).

Selection:

No. required: 4

*Make: Fisher and Porter Co.

*Size: 5 (0.27 to 2.7 gpm)

Installed cost: $90 each.

*For cost estimating purposes only.

[redacted]

[redacted] [redacted]

PRECIPITATION SECTION

The loaded strip solution is neutralized with ammonia to precipitate the uranium in the presence of excess sodium ions. The precipitate is pumped to a filter for recovery of the precipitate as product wet cake.

Precipitation Tank T-12 (A and B)

Duty:

To receive loaded aqueous strip solution, hold 24-hr capacity (284 gals), serve as tank for batch precipitation of U by neutralizing the loaded strip solution with ammonia.

Selection:

Tank

No. required: 2

Capacity: 365 gals (4-ft diam, 5 ft deep)

Material: wood

Agitator drive

No. required: 2

Power: 1-1/2 hp portable

Speed: 180 rpm

Shaft material: 316 S.S. covered with plastic

Impeller

No. required: 2

Type: 6-bladed turbine type or equivalent

Size: 12 in.

Material: 316 S.S. covered with plastic

Installed cost: $900 each. (Denver Equipment Co.)

[redacted] [redacted]

[redacted] [redacted]

Pump P-28

Duty:

To pump precipitated uranium slurry to the filter. Pump sized to empty the precipitation tank in 1 hour (4.7 gpm).

Selection:

No. required:	1
*Make:	Eastern Industries, Inc.
*Model:	F
*Capacity:	0-5 gpm
*Head:	11-35 ft
*Speed:	3,450 rpm
*Motor rating:	1/3 hp
Material:	316 S.S.

Installed cost: $195 each.

*For cost estimating purpose only.

[redacted]

[redacted]

SECONDARY STRIP SECTION

To strip Mo (and regenerate the amine) from U barren organic phase with sodium carbonate solution.

Secondary Strip Mixer Tank T-13

Duty:

To mix stripped organic extract and aqueous sodium carbonate solution.

Selection: (Identical to mixer tank T-2)

Tank

No. required: 1

Tank diam: 8 in.

Effective depth: 8 in.

Over-all depth: 14 in.

Material: Plastic lined steel

Agitator drive

No. required: 1

Power: 1/4 hp

Speed: 400 rpm

Shaft material: 316 S.S. covered with plastic

Impeller

No. required: 1

Type: 4-blade turbine

Size: 4-in. diam

Material: 316 S.S. covered with plastic

Installed cost: $810 each (United States Stoneware Co.)

[redacted]

[redacted]

Secondary Strip Settler Tank T-14

Duty:

To receive mixed phases from mix tank (T-13) and provide holdup time for the two phases to separate.

Selection: (Identical to interstage settler tank T-4B, C, and D)

No. required: 1

Diameter: 2.5 ft

Effective depth: 12 in.

Over-all depth: 18 in.

Material: Plastic lined steel

Installed cost: $550 each (United States Stoneware Co.)

Secondary Strip Aqueous Storage Tank T-15

Duty:

To hold 24-hr supply of sodium carbonate solution (95 gals) and serve as a head tank for strip solution flow to secondary strip mixer tank (T-13).

Selection:

No. required: 1

Capacity: 100 gals (30-in. diam, 36 in. deep)

Material: Steel

Installed cost: $120 each (Denver Equipment Co.)

Spent Aqueous Secondary Strip Storage Tank T-16

Duty:

To receive spent aqueous secondary strip solution, 24-hr capacity (95 gals).

[redacted]

[redacted]

Selection:

No. required: 1

Capacity: 100 gals (30-in. diam, 36 in. deep)

Material: Steel

Installed cost: $120 each (Denver Equipment Co.)

Aqueous Secondary Strip Feed Pump P-30

Duty:

To pump 0.066 gpm aqueous secondary strip solution from feed tank (T-15) to secondary stripper mixer (T-13).

Selection:

No. required: 2 tubes (one spare)

*Make: Brosites Machine Co.

*Model: Six-in-one proportioning pump, Model "O"

*Capacity: 0.0003 to 0.132 gpm (each tube)

*Head: 8 ft

*Motor rating: 1/20 hp

Material: Rubber

Installed cost: $415 each

Allocated cost: $138 (see pump P-31)

---

*For cost estimating purpose only.

[redacted]

[redacted]

APPENDIX B: OPERATING COST DETAILS

CHEMICAL COSTS

The amount and costs of chemicals consumed in a 24-hr period are shown in Table B-1.

TABLE B-1. DAILY CHEMICALS COST

Chemical	Quantity Required per day	Unit Cost[1]	Total Cost of Chemicals per day
Kerosene	4.6 gals	$0.14	$0.64
Amine	3.1 lbs	0.85	2.64
Sodium chloride	139.7 lbs	0.0075	1.05
Ammonia (anhydrous)	18.4 lbs	0.0575	1.06
Sodium carbonate[2]	88.7 lbs	0.0225	2.00
Sulfuric acid	0.1 lbs	0.015	0.00
Total			$7.39

1/ Cost at Grand Junction, Colorado.

2/ Used only when secondary strip operation is employed.

[redacted]

[redacted] [redacted]

LABOR SCHEDULE

The labor requirements and costs for the pilot plant are summarized in Table B-2 on a daily (24-hr) basis. The labor schedule was based on the assumption that the pilot plant would be located in the AEC Compound at Grant Junction and that other pilot plants would be in continuous operation (24 hours per day, 7 days per week) along with this pilot plant.

TABLE B-2. OPERATING LABOR REQUIREMENTS

Title	Duty	Number Required	Salary Each	Cost Per Day
Project leader	To direct operation of the pilot plant, analyze data and prepare reports	1	$600/mo	$19.73
Operator	Operate pilot plant	4 (one per shift)	$1.85 per hr1/	43.49
Day operator	Prepare special solutions, relieve for vacations, extra shift each week and sickness	1	$1.85 per hr	10.57
	Direct labor total			$73.79
	Payroll overhead2/			9.30
	Total			$83.09

1/ Swing shift differential 5¢/hr.
Graveyard shift differential 10¢/hr.

2/ 12.6% of direct labor.

[redacted] [redacted]

[redacted]

ELECTRIC UTILITY USAGE

The requirements for electrical utilities for the pilot plant are shown in Table B-3. Estimated power requirements were computed by applying a usage factor, based on local experience, to the installed power requirements.

TABLE B-3. PLANT ELECTRICAL REQUIREMENTS

Item No.	Quantity	Electrical Equipment	Installed HP Each	Installed HP Total	Usage %	HP Usage
T-1	3	Feed tank agitator	5.00	15.00	33	5.00
T-2	4	Extractor agitator	0.25	1.00	100	1.00
T-3	3	Stripper agitator	0.25	0.75	100	0.75
T-8	1	Organic storage agitator	1.00	1.00	34	0.34
T-10	1	Organic make-up agitator	0.25	0.25	4	0.01
T-11	2	Strip make-up agitator	1.50	3.00	17	0.50
T-12	2	Precipitation agitator	1.50	3.00	17	0.50
T-13	1	Secondary strip agitator	0.25	0.25	100	0.25
P-20	2	Leach liquor feed pump	0.33	0.67	50	0.33
P-21	2	Leach liquor raffinate pump	1.50	3.00	2	0.06
P-22	4	Leach liquor interstage pump	0.33	1.33	75	1.00
P-23	2	Organic pump to extractor	0.13	0.25	50	0.13
P-24	2	Barren organic pump	0.13	0.25	50	0.13
P-25	3	Interstage strip pump	0.17	0.50	66	0.33
P-26	1	Loaded organic pump	0.13	0.13	100	0.13
P-27	2	Strip feed pump	0.17	0.33	50	0.17
P-28	1	Precipitate pump to filter	0.33	0.33	4	0.01
P-29	1	Organic pump to secondary strip	0.13	0.13	100	0.13
P-30 (P-31)	1	Secondary strip feed pump	0.05	0.05	100	0.05
		Total horsepower		31.22		10.82
		Installed electricity		23.3		
		Used electricity				193.6 kwh

[redacted]