ENGINEERING RESEARCH INSTITUTE
THE UNIVERSITY OF MICHIGAN
ANN ARBOR

SOLVENT EXTRACTION STUDIES FOR RECOVERING URANIUM AND VANADIUM FROM LOW GRADE ORES

Progress Report No. 1

PRELIMINARY DESIGN OF A PILOT PLANT FOR THE EXTRACTION OF 1 KG/DAY OF U^{238} FROM RAW ORE

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Project D-120

March, 1956

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ABSTRACT

This report consists of a design of a pilot plant to extract one kilogram per day of U^{238} from raw ore by the direct acid leaching and selective solvent extraction process.

The final product consists of uranyl-chloride solution which may be processed to convert the salt into metal or recovered in the crystalline form.

Process design has been based on the use of Uravan stockpile ore, leached with dilute sulphuric acid. Flexibility of operation has been provided for the following:

(1) Use of any uranium ore or spent fuel,

(2) Leaching with any acid such as nitric, hydrochloric or hydrofluoric, and

(3) Solvent extraction with any organic solvent.

Material balances for uranium and vanadium and preliminary equipment specifications have been included.

The fixed capital investment for the pilot plant has been estimated at $177,000.

I. OBJECTIVES

The foremost objective of this paper is to present specifications for designing a pilot plant for the preparation of 1 kg/day of Uranium 238, from a Colorado Plateau raw uranium ore.

The pilot plant should be flexible enough to handle spent fuel from nuclear reactors and different ores of uranium.

The extraction process for uranium by selective liquid-liquid extraction in a pulse column should be utilized in preference to a chemical-separations process.

The design should include the following:

(1) Flow sheets for:

(a) dissolution in HNO_3, H_2SO_4, (Aq. 7.45M) HF,

(b) off-gas scrubbers,

(c) extraction columns,

(d) stripping columns,

(e) evaporation of uranyl solutions, and

(f) solvent recycle.

(2) Material balances in (a) no./day, no./hr., gph, gpd,

(3) Sizes for all equipment and controls,

(4) Preliminary specifications for: vessels, structures, etc., and

(5) Costs.

II. INTRODUCTION

Plant design for the extraction of uranium from raw ore depends essentially on the nature of the ore and the separation process. A pilot-plant design, however, calls for unusual flexibility of operation and for handling limiting conditions during experimentation or modifications. Certain parameters have to be fixed as a basis of design and sufficient leeway left for foreseeable changes in operation. For the present case, these parameters are (1) the ore to be processed and (2) the extraction process.

A. Description of the Ore

The ore selected for processing is the "Uravan" stockpile material. This is a composite sample representing a large quantity of ore, blended and stockpiled by the AEC, which will be processed in the near future.

The chemical composition of the ore is as follows:

U_3O_8	0.15 %
V_2O_5	1.90
SiO_2	87.00
CaO	1.12
MgO	0.85
Fe_2O_3	0.89
Al_2O_3	3.24
P_2O_5	0.09
CO_2	0.80

B. Description of the Process

The process selected is direct-acid leaching of the raw ore followed by hydroflouric-acid leaching to recover the unavailable uranium. Sulphuric acid is used for dissolution. The sulphuric acid leach solution containing the uranium, vanadium and other components is subjected to selective extraction with Dodecyl phosphoric acid or DDPA for the separation of uranium. The uranium is then stripped from DDPA by hydrochloric acid from which it may be recovered as a salt for metal processing.

C. Basis of Equipment Design

Equipment design has been based with one important factor in mind: flexibility of operation. Enough leeway has been incorporated to handle different systems and variables. It may appear at first sight that the equipment is oversized. This is the very purpose of the design.

Based on Uravan ore, the sulphuric acid requirements have been calculated and the acid makeup tanks designed. In case of any other ores, or for spent fuels, various acid strengths can be prepared without trouble.

The leaching unit has been provided with a flexibility far above that required for Uravan ore. Published data indicate that uranium from Uravan ore is easily dissolved by diluted acid solutions even at room temperatures. For application to ores difficult to dissolve, the leach columns have been steam jacketed and provided with reflux condensers, thus making operation at boiling solution temperatures possible. The time of digestion has been arbitrarily fixed as one hour. The design has been made with the view of probable use of spent fuel for recovery of uranium. The second leaching unit has been designed for the recovery of the unavailable uranium, by leaching with hydrofluoric acid. The second unit is identical to the first with the exception of the material of construction. This unit will also make possible the study of the HF-U system with the same plant. It is often advantageous to separate vanadium by a salt-roast process. A muffle furnace is provided for this purpose. In case this process need be studied, the first leaching unit may be used for extraction with water while the second may be used for extraction with acid. Acid extract tanks have been designed for a two-day hold-up.

The extraction column has been designed for operation from maximum flooding capacities to mixer-settler conditions. The number of plates is variable and the recovery of uranium with the present system is expected to be over 99%. The free space at the top is designed for 15 minute phase separation time at the maximum flooding capacity, viz, 3000 gal/hr sq ft. The pumps used have variable capacities which may be controlled by a by-pass system and have the capacities corresponding to the throughputs of the extraction column.

The stripping column handles comparatively a much smaller volume of liquid in the present case of Uravan ore and the organic solvent. However, the design has been based so as to accommodate any new system for experimentation and hence is made identical to the extraction column. For the present case, the stripping column will be operated for only about 1-1/2 hrs. a day. This may appear to be a form of idling of equipment, but would facilitate experimentation with new systems.

A solvent-processing unit has been introduced for purifying the solvent for recycle and for separating out the unstripped materials.

The volume of the acid solution from the stripper is so small that the concentration of uranium and recovery could be carried out in glass equipment on a bench scale. However, in case spent fuel is processed, an evaporator, condenser, etc., will be required and provision has been made on that basis. With the present system, .87 tons of ore processed per day for the recovery of about 1 kg U^{238}/day, the concentration of uranium in the strip solution is about 122 g/l. The total volume of the strip solution is about 2-1/4 gallons/day which, being a small amount, could be stored in ten-gallon bottles.

The further processing can be done on a batch scale rather than a continuous one. This would eliminate the entire "U concentration unit" for this particular system.

III. PILOT PLANT FOR EXTRACTION OF URANIUM FROM RAW ORE

A. Process Description

Process description will be read in conjunction with the flowsheet.

The acid-leach process followed by solvent extraction is selected for the uranium extraction. The pilot plant broadly consists of (1) Leaching Unit I, (2) Leaching Unit II, (3) Extraction Unit, (4) Stripping Unit, (5) Solvent Processing Unit, and (6) Solution Concentration Unit.

1. Leaching Unit I

This unit consists of an acid make-up tank (310-1), a preheater (212-1), a raw-ore feed-hopper (530-1), a leaching column (105-1), a reflux condenser (202-1), a cooler (105-1), a rotary filter (451-1), an ore receiver (550-1), and an acid-extract tank (501-1) with a diaphragm pump (400-1).

The leaching solution which could be either sulphuric or nitric acid is made up in the acid make-up tank (310-1) and preheated to a temperature of 176^{o}F in the heater (212-1). The temperature of the outgoing acid solution is maintained constant with a temperature control (601-1) in the heater. This acid solution is continuously fed to the leaching column (105-1). The raw ore ground to the required size is fed to the column from a raw-ore feed-hopper (530-1).

The leaching column is operated at the boiling point of the solution and heated by low-pressure steam. The digesting time is about one hour. The overhead vapors are condensed in the reflux condenser (202-1). The condensate is returned to the column and the noncondensibles vented to the stack. Compressed air may be bubbled through the column as an oxidizing agent and for stirring purposes.

The slurry from the leaching column is continuously removed, sent to the cooler (211-2) prior to being filtered in the rotary filter (451-1). The solids which contain the "unavailable uranium" are dumped in the ore receiver (550-1), dried in a compartment drier (700-1) and stored for use in the second leach column to recover the rest of the uranium. The filtrate containing the U_3O_8 in solution is stored in the acid extract tank (501-1) and pumped to the solvent-extraction column (100-1).

2. Leaching Unit II

This unit is identical to Leaching Unit I except that the material of construction is selected to resist the corrosive action of hydrofluoric acid. The slurry from the Leaching Column II (105-2) after cooling in the cooler (211-2) is separated in a "raffinate receiver and ore separator" (550-2) where the waste ore and the acid solution are separated by gravity. The clear solution is stored in the acid-extract tank (501-2) and sent for chemical separation of uranium.

To provide experimental flexibility, the raw ore may be roasted in the muffle furnace (300-1) before leaching. In such a case, the Leaching Unit I may be used for extraction of ore with water and Leaching Unit II may be used for extraction with acid. The same filter may be used for the solid separation and the extracts may be mixed or pumped individually to the Solvent Processing Unit.

3. Extraction Unit

The extraction unit consists of a pulse-plate column (100-1) with a pulser (410-1) generating variable types of pulses, a stripped solution storage tank (500-1) and an organic extract-storage tank (500-2).

The acid extract is fed to the top of the pulse column and the solvent to the bottom. The stripped-acid solution is removed from the bottom and stored in the stripped-solution tank (500-1) for recovery of vanadium. The organic phase rich in uranium is removed from the top and stored for use in the stripping column. The extraction column is designed for the study of pulse-column variables. The nature of pulsation, the number of plates, plate spacing, etc. may be varied at will. The organic solvent may be selected on the basis of the acid used for leaching. In the present case where sulphuric acid is used for leaching, .1 M DDPA in kerosene serves as an ideal solvent.

4. Stripping Unit

The stripping unit consists of the strip-makeup tank (310-3), the pulse column (100-2) with a pulse generator (410-2), and an acid solution storage tank (500-3). The organic phase is fed at the bottom of the column and the stripping solution is fed to the top of the column. The stripped organic phase is removed at the top and sent to the solvent processing unit. The acid solution, rich in uranium, is removed from the bottom and stored in the uranium-rich acid-solution tank for concentration of the uranium solution and for recovery of the acid.

5. Solvent-Processing Unit

The solvent-processing unit has essentially been provided for experimental facility. It consists of a series of mixer settlers (300-1, 300-2, and 300-3) where the solvent is treated with caustic acid and water or any washing solvent desired. The solvent is then recirculated to the extraction column.

6. Uranium-Concentration Unit

This consists of an evaporator (203-1), condenser (202-3), a uranyl solution storage tank (501-3) and acid-recycle solution tank (501-4). The solution is evaporated to increase the uranium concentration and to recover the acid used in the strip solution. The recovered acid may then be recycled to the stripping column. The uranium in solution is stored and may be processed for metal recovery or for separation as a salt.

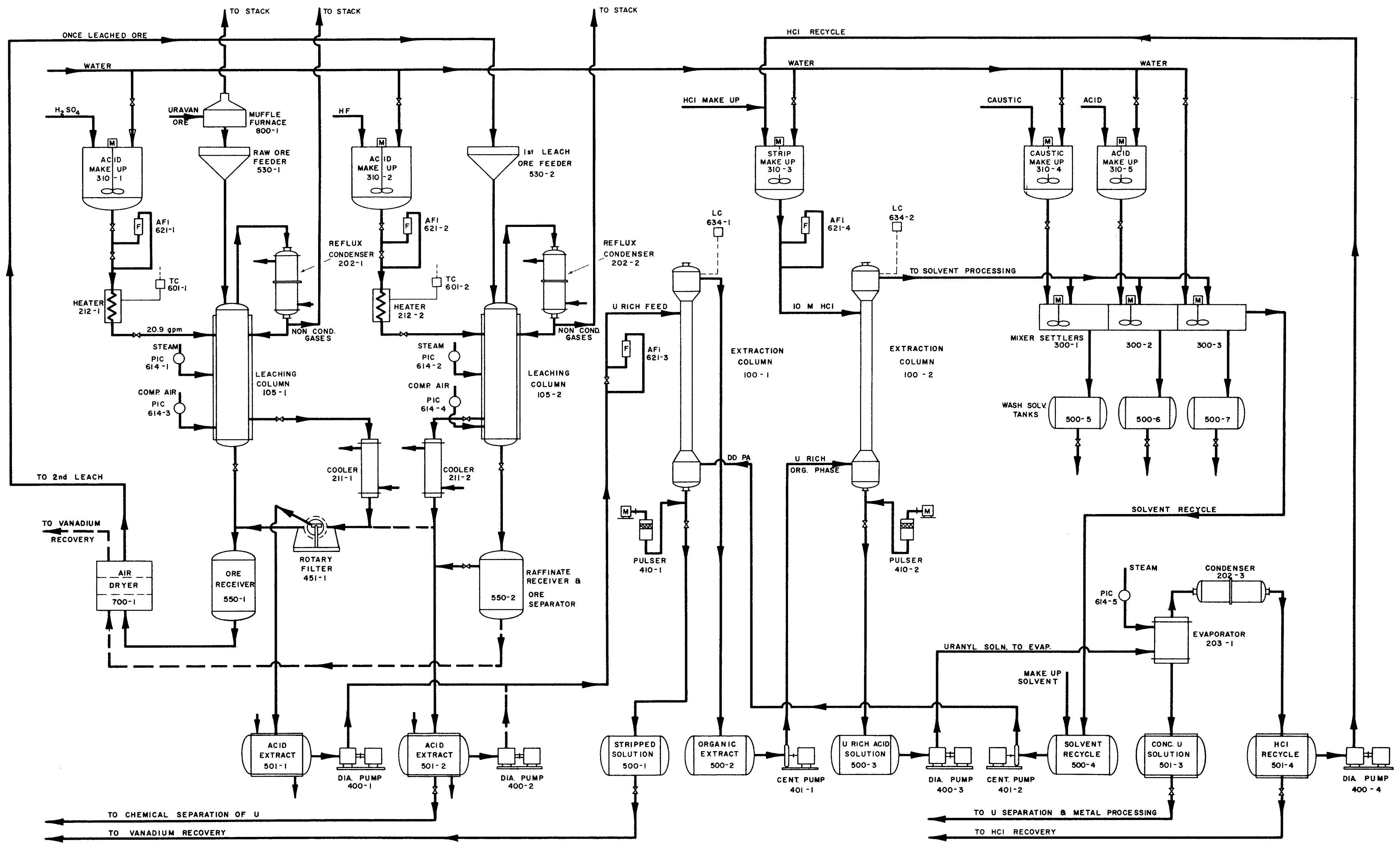

FIG. I - FLOW SHEET OF A PILOT PLANT FOR EXTRACTION OF URANIUM FROM RAW ORE

IV. PILOT PLANT ITEM LIST

Item No.	Description
100-1	Pulse plate column for extraction.
100-2	Pulse plate column for stripping.
105-1	Leaching Column I with steam jacket.
105-2	Leaching Column II with steam jacket.
202-1	Reflux condenser for leaching Column I.
202-2	Reflux condenser for leaching Column II.
202-3	Reflux condenser for evaporator.
203-1	Evaporator for uranyl solution.
212-1	Heater, steam coil type for acid solution.
212-2	Heater, steam coil type for acid solution.
211-1	Double pipe heat exchanger (acid resisting).
211-2	Double pipe heat exchanger (karbate material).
300-1	Mixer settler.
300-2	Mixer settler.
300-3	Mixer settler.
310-1	Acid make-up tank.
310-2	Acid make-up tank (HF resisting).
310-3	Acid make-up tank.
310-4	Caustic make-up tank.
310-5	Acid make-up tank.
400-1	Acid extract pump (diaphragm type).
400-2	Acid extract pump (diaphragm type).
400-3	Acid extract pump (diaphragm type).
400-4	Acid recycle pump (diaphragm type).
401-1	Organic extract pump (centrifugal).
401-2	Solvent recycle pump (centrifugal).
410-1	Variable pulse generator.
410-2	Variable pulse generator.
451-1	Rotary filter (acid resisting).

Item No.	Description
500-1	Stripped acid solution storage tank.
500-2	Organic extract solution storage tank.
500-3	Rich acid extract solution storage tank.
500-4	Solvent recycle tank.
500-5	Caustic wash solution tank.
500-6	Acid wash solution tank.
500-7	Aqueous wash solution tank.
501-1	Acid extract storage tank.
501-2	Acid extract storage tank.
501-3	Uranyl solution storage tank.
501-4	Acid recycle solution storage tank.
530-1	Raw ore feed hopper.
530-2	"Once leached ore" feed hopper.
550-1	Ore receiver.
550-2	Raffinate receiver.
601-1	Temperature control (indicating type, item no. 212-1).
601-2	Temperature control (indicating type, item no. 212-2).
614-1	Pressure controller (steam; item no. 105-1).
614-2	Pressure controller (steam; item no. 105-2).
614-3	Pressure controller (steam; item no. 203-1).
614-5	Pressure controller (air; item no. 105-1).
614-6	Pressure controller (air; item no. 105-2).
621-1	Flow indicator (area type; item no. 310-1).
621-2	Flow indicator (area type; item no. 310-2).
621-3	Flow indicator (area type; item no. 100-1).
621-4	Flow indicator (area type; item no. 310-3).
634-1	Level controller, item no. 100-1.
634-2	Level controller, item no. 310-3.
700-1	Air compartment dryer.
800-1	Gas muffle furnace.

Total number of items (59).

V. PRELIMINARY EQUIPMENT SPECIFICATIONS

Vessels

a. Leaching Column - Item nos. 105-1 - 105-2

No. required	- 2 (two)
Type	- Solid-liquid extraction column, steam jacketed
Size	- 1.25' I. D. 6.5' Height
Steam jacket	- Bottom to 1' from top
Operating pressure	- Atmospheric
Operating temp.	- 300°F
Material of construction	- 1) Glass lined steel 2) Rubber lined steel

b. Extraction column - Item nos. 100-1 - 100-2

No. required	- 2 (two)
Type	- Pulse plate column
Diameter of column	- 2.5"
Height	- 8'
Headers (top and bottom)	
Diameter	- 12"
Height	- 12"
Plate adjusting device	- Center rod, threaded (st. st.)
Operating pressure	- Atmospheric
Operating temp.	- Room temp.
Material of construction	- Glass

c. Acid-Makeup Tank - Item nos. 310-1 - 310-2

No. required	- 2 (two)
Type	- Vertical with mech. agitator
Size	- I. D. = 3' H = 2.25'
Capacity	- 125 gal.
Operating pressure	- Atmospheric
Operating temp.	- Room temp.
Material of construction	- Steel, glass lined

d. Preheater - Item nos. 212-1 - 212-2

No. required	- 2 (two)
Type	- Vertical glass lined with steam coil, automatic temp. control
Capacity	- 62.5 gal.
Steam coil area for heat transfer	- 2.35 sq. ft.
Duty	- 17,500 Btu/hr.
Operating pressure	- Atmospheric
Operating temp.	- 200°F
Material of construction	- 1) steel, glass lined 2) steel, rubber lined

e. <u>Ore Feed Hopper</u> - Item nos. 530-1 - 530-2

No. required - 2 (two)
Type - Conical, (L = D)
Size - D = 3.5'
L = 3.5'
Material of construction - C. I.

f. <u>Reflux Condenser</u> - Item nos. 202-1 - 202-2

No. required - 2 (two)
Duty - 61,500 Btu/hr.
Area of heat transfer - 6 sq. ft.
Type - Shell and tube
Operating pressure - Atmospheric
Operating temp. - $212^{o}F$
Material of construction - 1) steel shell, st. st. tubes
2) steel shell, karbate tubes

g. <u>Cooler</u> - Item nos. 211-1 - 211-2

No. required - 2 (two)
Type - Shell and tube
Duty - 25,000 Btu/hr.
Area of heat transfer - 15 sq. ft.
Operating pressure - Atmospheric
Operating temp. - $212^{o}F$
Material of construction - 1) steel shell, st. st. tubes
2) steel shell, karbate tubes

h. <u>Ore Receiver</u> - Item no. 550-1

No. required - 1 (one)
Type - Vertical tank, open (vat)
Size - I. D. = 3.0'
L = 2.5'
Material of construction - Wood

i. <u>Acid Extract Storage Tank</u> - Item nos. 501-1 - 501-2

No. required - 2 (two)
Type - Horizontal with cooling coils
Size - I. D. = 3.5'
L = 5.5'
Capacity - 350 gal.
Operating pressure - Atmospheric
Operating temp. - Room temp.
Material of construction - 1) glass lined steel
2) rubber lined steel

j. <u>Raffinate Receiver and Ore Separator</u> - Item no. 550-2

No. required - 1 (one)

	Type	- Vertical with slanting bottom
	Size	- D = 3' H = 5.5'
	Capacity	- 250 gal.
	Material of construction	- Rubber lined steel
k.	<u>Stripped Acid Solution Tank</u>	- Item no. 500-1
	No. required	- 1 (one)
	Type	- Horizontal
	Size	- I. D. = 3.5' L = 5.5'
	Capacity	- 330 gal.
	Operating pressure	- Atmospheric
	Operating temp.	- Room temp.
	Material of construction	- Glass lined steel
l.	<u>Organic Extract Tank</u>	- Item no. 500-2
	No. required	- 1 (one)
	Type	- Horizontal
	Capacity	- 150 gal.
	Operating pressure	- Atmospheric
	Operating temp.	- Room temp.
	Material of construction	- Steel
m.	<u>Uranium Rich Acid Solution Tank</u>	- Item no. 500-3
	No. required	- 1 (one)
	Type	- Horizontal
	Capacity	- 60 gal.
	Operating pressure	- Atmospheric
	Operating temp.	- Room temp.
	Material of construction	- Glass lined steel
n.	<u>Solvent Recycle Tank</u>	- Item no. 500-4
	No. required	- 1 (one)
	Type	- Horizontal
	Capacity	- 200 gal.
	Operating pressure	- Atmospheric
	Operating temp.	- Room temp.
	Material of construction	- Steel
o.	<u>Conc. Uranium Solution Tank</u>	- Item no. 501-3
	Capacity	- 25 gal.
	Type	- Vertical
	Material of construction	- Porcelain

p. Solvent Recycle Tank - Item no. 501-4

Capacity	- 25 gal.
Material of construction	- Glass or porcelain

q. Mixer Settlers - Item nos. 300-1 - 300-2 - 300-3

No. required	- 3 (three)
Capacity	- 16.7 gal.
Material of construction	- Stainless steel

r. Strip Solution Makeup Tank - Item no. 310-3

No. required	- 1 (one)
Type	- Vertical with agitator
Capacity	- 25 gal.
Material of construction	- Porcelain

s. Evaporator - Item no. 203-1

Type	- Steam jacketed, open pan type, with dished top and condenser.
Area of heat transfer	- 3 sq. ft.
Duty	- 10,000 Btu/hr.
Size	- 1.5' D., hemispherical
Material of construction	- Jacketed, glass lined steel

2. Auxiliary Equipment

a. Air Dryer - Item no. 700-1

No. required	- 1 (one)
Type	- Compartment dryer, with air blower, electrical coils for heating, damper for air rate adjustment, shelves for solids handling.
Size	- 4' x 2' x 4' L D H
Duty	- 173,000 Btu/day
Material of construction	- Stainless steel

b. Rotary Filter - Item no. 451-1

No. required	- 1 (one)
Type	- Vacuum connection, washing arrangements, etc. (oliver filter).
Capacity	- 21 gal/hr filtrate
Size	- D = 1' L = 1'
Filter cloth	- Tafflon
Area	- 3.14 sq. ft.
Material of construction	- Stainless steel

c. Gas Muffle Furnace - Item no. 800-1

No. required	- 1 (one)
Dimensions	- 2.5' x 2' x 3'
Type	- Gas muffle, oxidizing atmosphere
Operating temperature	- 800°C

3. Mechanical Equipment

a. Diaphragm pump - Item nos. 400-1 - 400-2

No. required	- 2 (two)
Capacity	- 20-100 gal/hr.
Head required	- 20'
Material of construction	- Stainless steel

b. Centrifugal Pump - Item nos. 401-1 - 401-2

No. required	- 2 (two)
Capacity	- 10-50 gal/hr.
Head required	- 20'
Material of construction	- Steel

c. Pulse Generator - Item nos. 410-1 - 410-2

No. required	- 2 (two)
Type	- Variable pulse, amplitude, and frequency

d. Diaphragm Pump - Item nos. 400-3 - 400-4

No. required	- 2 (two)
Capacity	- 20 gal/hr.
Head required	- 20'

VI. MATERIAL BALANCE

A. Leaching Column

FEED

Stream	Component	lbs/day	lbs/hr.	kg/day	g/hr.	gal/hr.	gal/day	litres/hr.
Ore	U_3O_8	2.6	.325	1.18	147.5	-	-	-
	V_2O_5	33.0	4.125	14.95	1,856	-	-	-
	Others	1,700	212.5	735.9	91,996	-	-	-
	Total	1,736	217	752.0	94,000	-	-	-
Acid	H_2O	1,330	166.25	603	75,370	19.9	159.5	75.2
	H_2SO_4	70	8.75	31.75	3,970	1.0	7.5	3.78
	Total	1,400	175	639.75	79,300	20.9	167	79

PRODUCT

Stream	Component	lbs/day	lbs/hr.	g/hr.	gal/hr.	gal/day	lbs/gal	g/l
Ore (Raffinate)	U_3O_8	0.08	.010	4.53	-	-	-	-
	V_2O_5	16.55	2.062	935.3	-	-	-	-
Acid (Extract)	Solution	1,400	175	79,380	20.9	167	8.42	1.01
	U_2O_8	2.52	.315	142.9	-	-	.0151	1.809
	V_2O_5	16.55	2.062	935.3	-	-	.0987	11.84
	Total	1,419	177.38	80,458	20.9	167	-	-

B. Extraction Column

FEED

Stream	Component	lbs/day	lbs/hr.	g/hr.	gal/hr.	gal/day	lbs/gal	g/l
Acid	Solution	1,400	175	79,380	20.9	167	8.42	1.01
	U_3O_8	2.52	.315	142.9	-	-	.0151	1.809
	V_2O_5	16.55	2.062	935.3	-	-	.0987	11.84
	Total	1,419	177.38	80,458	20.9	167	-	-
Organic	Solvent	236.5	29.6	1,343	4.18	33.5	7.08	0.85

PRODUCT

Stream	Component	lbs/day	lbs/hr.	g/hr.	gal/hr.	gal/day	lbs/gal	g/l
Acid	Solution	1,400	175	79,380	20.9	167	8.42	1.01
(Raffinate)	U_3O_8	.024	.003	1.36	-	-	.00014	.017
	V_2O_5	15.49	1.935	878	-	-	.0926	11.1
	Total	1,415.5	176.9	80,259	20.9	167	-	-
Organic	Solvent	236.5	29.6	1,343	4.18	33.5	7.08	0.85
(Extract)	U_3O_8	2.496	.312	141.5	-	-	.0398	4.78
	V_2O_5	1.06	.127	57.6	-	-	.0162	1.95
	Total	240	30.04	1,542.1	4.18	33.5	-	-

C. Stripping Column

FEED

Stream	Component	lbs/day	lbs/hr.	g/hr.	gal/hr.	gal/day	lbs/gal	g/l
Organic	Solvent	236.5	29.6	13,430	4.18	33.5	7.08	.850
	U_3O_8	2.496	.312	141.5	-	-	.0398	4.78
	V_2O_5	1.06	.127	57.6	-	-	.0162	1.95
	Total	240.1	30.0	13,600	4.18	33.5	-	-
Acid	Solution	24.01	3.0	1,360	.305	2.44	9.83	1.180

PRODUCT

Stream	Component	lbs/day	lbs/hr.	g/hr.	gal/hr.	gal/day	lbs/gal	g/l
Organic	Solvent	236.5	29.6	1,343	4.18	33.5	7.08	.850
(Raffinate)	U_3O_8	0.025	.003	1.34	-	-	.0007	.085
	V_2O_5	-	-	-	-	-	-	-
	Total	236.53	29.6	1,344	4.18	33.5	-	-
Acid	Solution	24.01	3.0	1,360	.305	2.44	9.83	1.18
(Extract)	U_3O_8	2.471	.309	140.16	-	-	1.011	121.5
	V_2O_5	1.06	.127	57.6	-	-	.417	50
	Total	27.56	3.436	1,557.8	.305	2.44	-	-

$$\text{Total } U^{238}/\text{day} = \left(2.471\ \frac{\text{lbs}}{\text{day}}\right)\left(.4536\ \frac{\text{kg}}{\text{lbs}}\right)\left(\frac{714}{842}\ \frac{U_3^{238}}{U_3O_8}\right)\ \text{kg/day}$$

$$= .99\ \text{kg/day}$$

VII. COST ESTIMATION

A. Equipment Costs

Item No.	Description	Material of Construction	Cost $	Total $
100-1	Pulse plate column	Glass	600	
100-2	Pulse plate column	Glass	600	1,200
105-1	Leaching column	Glass lined steel	2,500	
105-2	Leaching column	Rubber lined steel	2,500	5,000
202-1	Reflux condenser	Steel shell st. st. tubes	600	
202-2	Reflux condenser	Steel shell st. st. tubes	600	
202-3	Reflux condenser	Steel shell st. st. tubes	300	1,500
203-1	Evaporator	Jacketed, glass lined	1,000	1,000
212-1	Heater with steam coils	Glass lined steel	1,000	
212-2	Heater with steam coils	Rubber lined steel	1,000	2,000
211-1	Heat exchanger	Steel shell, st. st. tubes	1,000	
211-2	Heat exchanger	Steel shell, karbate tubes	1,000	2,000
300-1	Mixer settler	Stainless steel	300	
300-2	Mixer settler	Stainless steel	300	
300-3	Mixer settler	Stainless steel	300	900
310-1	Acid makeup tanks	Glass lined steel	1,250	
310-2	Acid makeup tanks	Glass lined steel	1,250	
310-3	Acid makeup tanks	Porcelain	300	
310-4	Acid makeup tanks	Porcelain	200	
310-5	Acid makeup tanks	Porcelain	200	3,200
400-1	Diaphragm pumps		200	
400-2	Diaphragm pumps		200	
400-3	Diaphragm pumps		200	
400-4	Diaphragm pumps		200	800
401-1	Centrifugal pump	Steel	200	
401-2	Centrifugal pump	Steel	200	400
410-1	Pulser		1,000	
410-2	Pulser		1,000	2,000
451-1	Rotary filter	st. st.	2,500	2,500
500-1	Acid solution storage tank	Glass lined steel	2,000	
500-2	Organic solvent tank	Steel	350	
500-3	Acid extract tank	Glass lined steel	1,000	
500-4	Solvent recycle tank	Steel	500	
500-5	Caustic solution tank	Porcelain	200	
500-6	Acid solution tank	Porcelain	200	
500-7	Aqueous solution tank	Porcelain	200	4,450

Equipment Costs (continued)

Item No.	Description	Material of Construction	Cost	Total
501-1	Storage tanks	Glass lined steel	2,000	
501-2	Storage tanks	Rubber lined steel	1,500	
501-3	Storage tanks	Porcelain	200	
501-4	Storage tanks	Porcelain	200	3,900
530-1	Feed hopper	C. I.	300	
530-2	Feed hopper	C. I.	300	600
550-1	Ore receiver	Wood	50	
550-2	Raffinate receiver	Rubber lined steel	1,250	1,300
700-1	Air dryer	Stainless steel	1,500	1,500
800-1	Muffle furnace		2,000	2,000
	Total Equipment Cost			$36,250

B. Fixed Capital Investment

Purchased Equipment Cost	$ 36,250
Installation cost, (43% equipment cost)	15,160
Instrumentation	2,500
Piping, (86% equipment cost)	30,500
Installation cost for piping (43% piping cost)	13,100
Electrical auxiliaries, (10% equipment cost)	3,600
Buildings, (80% equipment cost)	28,200
Utilities, (20% equipment cost)	7,250
TOTAL	$ 139,460

Physical plant cost	$ 140,000
Engineering and construction, (15% physical cost)	21,000
Direct plant cost	$ 161,000
Contractor's fee	16,000
TOTAL	$ 177,000

Fixed Capital Investment	$ 177,000