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FINAL REPORT

on

DESIGN CONSIDERATIONS FOR AN AMMONIUM
CARBONATE LEACH PILOT PLANT

to

DIVISION OF RAW MATERIALS
UNITED STATES ATOMIC ENERGY COMMISSION

by

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DESIGN CONSIDERATIONS FOR AN AMMONIUM CARBONATE LEACH PILOT PLANT

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BMI-284

A 12-ton-per-day pilot plant was designed for extracting uranium from ores by the ammonium carbonate pressure-leach process.

The design information consists of equipment specifications, equipment-fabrication drawings, process flowsheets, plant layout, and design calculations.

INTRODUCTION

In September, 1948, experiments at Battelle showed that uranium, solubilized in ammonium carbonate-bicarbonate solutions, could be precipitated by expelling the ammonia and carbon dioxide. The idea of extracting uranium from unoxidized or partially oxidized ores by ammonium carbonate-bicarbonate leaching under pressure with air or oxygen was discussed in Ottawa at a joint meeting with representatives of the AEC and the Canadian Mines Branch in March, 1954. This led to the development of the ammonium carbonate pressure leach for the extraction of uranium from the ores of the Colorado Plateau.

Such a process would have the inherent economic advantage of a low reagent cost, providing that ammonia could be recovered cheaply. Therefore, if the cost of leaching could be held to a nominal figure, the over-all economics of the process might prove attractive.

In addition to the low reagent cost, the ammonium carbonate process offered the same advantage as sodium carbonate leaching, that is, the presence of lime in the ore does not affect the reagent consumption.

The Atomic Energy Commission authorized Battelle under Contract No. AT(49-6)-921 to work on the ammonium carbonate leach process. Laboratory experiments were conducted from August, 1954, to July, 1955, on ores which might be fed to the pilot plant at Grand Junction. This work included a study of the effect of the operating variables on the extraction of uranium and the construction and operation of an integrated plant capable of treating 30 pounds per hour of ore. Data and results of the laboratory work were recorded in BMI Reports Nos. 281, 282, and 283.

The data obtained from this program showed the process to be technically sound and provided valuable design information for future use.

This report describes the design of a 12-ton-per-day pilot plant for the ammonium carbonate pressure leaching of uranium ores. The process is fundamentally the same as that used in the 30-pound-per-hour integrated plant but with modifications of equipment design to give better operating economy.

DESCRIPTION OF PROCESS

Processing Steps

Figures 1, 2, and 3 show the process flow plans which are possible with the 12-ton-per-day pilot-plant design. For convenience, the process may be divided into the following steps for the purpose of description.

Grinding

Either the wet-grinding circuit shown in Figures 1 and 2 or the dry-grinding circuit shown by Figure 3 may be used. In either case, it is important to provide minus 100-mesh solids for successful operation of the pressure-leaching step which follows.

The ore leaves the grinding circuit at a pulp density of 50 per cent solids in an ammonium carbonate-bicarbonate solution.

Leaching

The pulp is leached at 185 to 250 F and under pressures up to 250 psi by passing through four vertical pipes in series. Air or oxygen can be admitted into the leach vessels at several places.

Pulp at 50 per cent solids would in most cases be at terminal density. This is desirable for good operation of the towers since the linear velocity of the pulp flowing through the leaching system is very low.

Pressure Letdown and Gas-Pulp Separation

The mixture of hot pulp and air leaves the leaching system under pressure and is cooled to at least 110 F by going through a heat exchanger using either water or pregnant solution for the coolant. The cooled mixture passes into a gas-liquid separator where the gases are released to the atmosphere at whatever back pressure is desired on the system. The liquid-pulp phase leaves the vessel intermittently through a solenoid valve controlled by the liquid level.

Wet grinding circuit.
Pulp density in CCD (33.3 per cent solids).

FIGURE 3. PROCESS FLOW SHEET FOR AMMONIUM CARBONATE LEACH PILOT PLANT, PLAN 3

Dry grinding circuit.
High pulp density in CCD (33.3 per cent solids).

Liquid-Solid Separation

A four-stage CCD system separates the pregnant solution from the solid residue, reducing soluble uranium and ammonia losses to a minimum.

Ammonia Recovery and Uranium Precipitation

The pregnant solution from the CCD system containing 1.0 to 3.0 grams of uranium per liter goes to a steam stripper where ammonia and carbon dioxide are expelled and uranium precipitated. The chemical reactions are:

The liquid from the bottom of the stripper contains the precipitated uranium and is pumped to metal recovery.

The vapor from the steam stripper, except for a part of the carbon dioxide, is cooled and condensed as an ammoniacal solution. This solution is strong enough in ammonia to be used for recycling to the grinding circuit.

Carbon Dioxide Recovery

Carbon dioxide which is not held in solution in the ammonia recovery system is contacted again with the ammoniacal condensate in a packed tower. In addition, make-up carbon dioxide is added here.

Metal Recovery

The precipitated uranium from steam stripping is collected by a filter press. Calcination of the $\text{UO}_3 \cdot 2\text{H}_2\text{O}$ cake converts it to U_3O_8 .

Process Variables

Grind

Grinding the ore to minus 100 mesh provides sufficient particle surface area for fast leaching and gives desirable pulp-handling properties. Grinding finer than minus 100 mesh has not been shown to be worthwhile.

Leaching Time

Tests at Battelle showed that the time for maximum uranium extraction varied with the ore, temperature, and reagent concentration. However, the leaching time is not expected to exceed 6 hours.

Pulp Density

Pulp densities of about 50 per cent solids are desirable since this would approach terminal density and reduce the tendency to sand out in the towers. Some ores tested at 50 per cent pulp density were too viscous to pump and required dilution to a lower density. However, it is believed that this high viscosity was due to overaddition of Separan. Future work may show that any ore can be pumped at a pulp density of 50 per cent solids.

Leaching Temperature

The effect of temperature on leaching time varies markedly with the ore. Leaching temperatures may range from 185 to 250 F. In general, higher temperatures increase the reaction rate.

Reagent Concentrations

Tests at Battelle showed that a solution concentration equivalent to 100 grams of ammonium carbonate and 20 grams of ammonium bicarbonate per liter gave good extraction of uranium from the ores.

Air Addition

Small-scale batch testing indicated that oxidation of the pulp during leaching was important. Experimental runs on the 30-pound-per-day integrated plant showed little change in extraction for the range of air flows investigated. According to these data, only 5 scfm of air is required for the 12-ton-per-day pilot plant. This scaleup is based on providing a certain scfm per tower cross section.

Uranium Precipitation Conditions

According to laboratory results maximum precipitation occurs at pH 7 or 8. Below pH 7 some uranium may redissolve.

The injection of live steam into the pregnant solution is believed to aid nucleation of the precipitate.

A retention time of 1 hour may be desirable to allow complete precipitation of the stripped solution.

Process Flows

Figures 1, 2, and 3 show the three flow plans possible with the pilot plant. Flowsheet calculations assumed 0.27 per cent uranium in the ore and 93 per cent extraction of the uranium.

Figures 1 and 2 used the same equipment. According to Figure 2, 16 tons per day of fresh or recycle water go into the CCD system giving 33.3 per cent solids pulp to each thickener. A portion of the pregnant solution stream from the CCD system can bypass the steam stripper.

According to Figure 1, 26 tons per day of fresh or recycle water go into the CCD system giving 26 per cent solids pulp to each thickener. Because of its lower NH_3 concentration the entire pregnant solution stream must be steam stripped to provide enough ammonia in the condensate for recycling.

The relative merits of the two flow plans shown by Figures 1 and 2 are as follows:

Figure 1 - Less ammonia loss in the CCD system due to the lower ammonia concentration.

Figure 2 - Less steam required for stripping the pregnant solution.

Figure 3 is a flow plan similar to Figure 2 but substitutes dry grinding for wet grinding. Since a large part of the ammonia loss is estimated to be in the grinding circuit, a considerable reagent savings would result.

The relative cost of steam and ammonia would dictate the choice of Plans 1 or 2.

Assuming steam to cost \$0.50 per 1000 pounds and ammonia at \$0.05 per pound, the following tabulation is of interest.

	Plan 1		Plan 2		Plan 3	
	Lb/Ton	\$/Ton	Lb/Ton	\$/Ton	Lb/Ton	\$/Ton
	Ore	Ore	Ore	Ore	Ore	Ore
NH_3 Loss	9.58	0.479	12.4	0.620	4.5	0.225
Steam for Stripping	1470	0.735	655	0.328	655	0.328
Total		1.214		0.948		0.553

Estimation of Ammonia Loss

Equations for the evaporation per unit area for water from cooling ponds have been developed and are based on considerable experimental data. An estimate of ammonia or carbon dioxide loss can be made by correcting the value obtained for water. The following fundamental relation applies for constant temperature

$$\frac{N_{\text{NH}_3}}{N_{\text{H}_2\text{O}}} \propto \left(\frac{P_{\text{NH}_3}}{P_{\text{H}_2\text{O}}} \right) \frac{D_{\text{NH}_3}}{D_{\text{H}_2\text{O}}}$$

where N_{NH_3} = mols NH_3 evaporating/(hr)(sq ft)
 $N_{\text{H}_2\text{O}}$ = mols H_2O evaporating/(hr)(sq ft)
 P_{NH_3} = partial pressure of NH_3 over the solution
 $P_{\text{H}_2\text{O}}$ = vapor pressure of H_2O
 D_{NH_3} = diffusion coefficient of NH_3 , sq ft/hr
 $D_{\text{H}_2\text{O}}$ = diffusion coefficient of H_2O , sq ft/hr.

A similar relationship exists for carbon dioxide.

The diffusion coefficients can be calculated accurately. Experimental vapor pressure for ammonia in the ammonia-carbon dioxide-water system are available for a range of concentrations and temperatures in Gmelin's Handbuch der Anorganischen Chemie, Volume 8, page 334. Fortunately the concentrations given are quite close to those required.

When the amount of ammonia evaporating per unit of area is calculated by this method, the total ammonia loss is estimated by multiplying by the exposed area. It is evident that the evaporation loss can be cut down appreciably by covering equipment handling ammoniacal solutions.

Ammonia losses for Flow Plan 1 are given below.

The left-hand column of figures are the losses which would result if no effort is made to cover the equipment. The right-hand column assumes that some effort has been made to cover the equipment. The exposed area of a rotating ball mill is strictly a guess.

	<u>NH₃ Loss, lb/day, Uncovered Equipment</u>	<u>NH₃ Loss, lb/day, Covered Equipment</u>
<u>Grinding Circuit</u>		
Thickener	82.5	25.0
Classifier	18.0	18.0
Ball Mill	32.0	32.0

	<u>NH₃ Loss, lb/day, Uncovered Equipment</u>	<u>NH₃ Loss, lb/day, Covered Equipment</u>
<u>CCD System</u>		
No. 1 Thickener	55.5	15.0
No. 2 Thickener	17.10	5.0
No. 3 Thickener	4.27	4.0
No. 4 Thickener	1.07	1.0

The other ammonia losses in the system are as follows:

Pressure-letdown system	2 lb/day
Soluble loss in tails	4 lb/day
Precipitator bottoms	9 lb/day

A temperature of 104 F was assumed in the evaporation-loss calculation.

Ammonia losses for Flow Plans 2 and 3 are shown on the flowsheets, Figures 2 and 3.

Ammonia losses are sensitive to temperature and solution concentration. A temperature of 104 F was assumed in the estimation. Higher operating temperatures and concentrations will produce higher losses.

Perhaps the greatest value of this estimate is that it points out which pieces of equipment should be covered and to what extent.

One other source of ammonia loss should be mentioned. If flue gas is used as a source of carbon dioxide, the loss of ammonia in the vent gas from the carbon dioxide absorber will be very large. A loss of 100 pounds of ammonia per day could result here because of the large volume of gas which must pass through the tower when the carbon dioxide concentration is low. For this reason, the use of pure carbon dioxide for the pilot plant was recommended.

DESCRIPTION OF EQUIPMENT

The relation of the various pieces of equipment to one another and to the processing circuit is shown by the flowsheets, Figures 1, 2, and 3.

Drawings 13A, 13B, and 13C, in Appendix B, show the physical location of the equipment by plan and elevation views.

Equipment details are given by the specifications in Appendix A or drawings in Appendix B, or both.

Design calculations are given in another section.

This section of the report discusses briefly the major units of the ammonium carbonate leach process.

Wet-Grinding Circuit

A 3-foot x 2-foot ball mill, a 1 foot-6-inch by 13-foot rake classifier and a 12-foot thickener make up the wet-grinding circuit. All of this equipment is in place at the alkaline-leach pilot plant at Grand Junction.

Calculations lead to the specification of a slightly larger ball mill, 3 foot x 3 foot. However, the present one may do the job.

According to the ammonia-loss estimates, it would be desirable to cover this equipment. However, only the thickener can be covered easily. It is suggested, therefore, that this be done. If ammonia vapors from the ball mill and rake classifier prove to be a nuisance, then an effort will have to be made to cover them.

Dry-Grinding Circuit

Process Flow Plan 3 shows replacement of wet grinding with dry grinding. This eliminates one of the principal sources of ammonia loss and is recommended over wet grinding for this reason.

Principal components of the dry-grinding circuit are: constant-weight feeder; 4-1/2-foot x 16-inch conical ball mill; air-classifier system with dust collector.

Leach Towers

Four vertical steam-jacketed vessels, 16 inches in diameter x 25 feet, are specified for pulp leaching. At the design feed rate of 12 tons of ore per day, the towers provide a total of 6 hours' retention time with 50 per cent solids pulp density.

Each tower is made up of three steam jacketed sections plus the two ends. The top and middle sections are interchangeable while the bottom section differs from the upper two.

Openings are provided for air injection or for sampling.

The vessels are designed for a working pressure of 250 psig at 300 F.

Heat Exchanger for Cooling Slurry

The exchanger must cool 2000 lb/hr of hot leached pulp (50 per cent solids) from 270 to 110 F by heating aqueous ammonium carbonate solution from 90 to 170 F. Cooling water can serve as an alternative. It would be well to pipe the exchanger so that either pregnant solution or cooling water can be used.

A double-pipe heat exchanger is recommended for this application whereby the slurry passes through the inner pipe and the coolant through the annular space. The area of 1-inch schedule 80 pipe inside would provide sufficient velocity for good heat transfer but the velocity would still be low enough to reduce abrasion by the solids. The schedule 80 pipe is recommended from the standpoint of abrasion rather than pressure.

About 232 feet of pipe length are required. The diameter of the outside pipe is not critical. Either a 1-1/2-inch or 2-inch schedule 40 pipe should prove satisfactory.

The return bends at the ends of the exchanger should be removable rather than welded.

CCD System

Four stages are specified to reduce soluble uranium and ammonia loss to a low level. Twelve-foot-diameter thickeners are large enough for this proposed plant.

Ammonia loss calculations show that at least the first two stages should be covered.

NH₃-CO₂ Stripping and Uranium Precipitation Tower

The economy of the whole process depends on steam consumption. Therefore, a very efficient machine for recovering ammonia must be employed. A 30-plate steam stripping tower was designed to accomplish the recovery of a concentrated ammoniacal solution with low steam consumption. A special plate was designed for operation in liquids where precipitation takes place. All plates are removable and can be reached from the manholes provided along the sides.

The long lower section of tower below the plates provides additional retention time for completing the precipitation.

Condenser

This apparatus must cool and condense as much as possible of the vapor mixture from the steam stripper. Nearly all the ammonia and water is expected to condense here. The amount of carbon dioxide held in solution is unknown. Uncondensed carbon dioxide must be vented to the carbon dioxide-recovery tower.

A shell and tube condenser is recommended for this function.

Condensate Subcooler

A subcooler is recommended for the following reasons: (1) A cool liquid is essential for the carbon dioxide absorption. (2) It is difficult to subcool in the condenser. (3) The heat of solution of make-up ammonia should be removed.

A small double-pipe heat exchanger is recommended. About 50 feet of 1/2-inch pipe is adequate. The exchanger may be of welded construction and the return bends need not be removable.

CO₂ Absorption Tower

A 10-foot packed bed is specified for absorption of makeup and recycle carbon dioxide in ammoniacal solution.

Tower packing can be 1-inch berl saddles or raschig rings.

EQUIPMENT-DESIGN CALCULATIONS

Design calculations for the more critical units are included here. It is hoped that they will be of particular use for estimating changes in performance due to changes in operating conditions.

Ball Mill (Item 1)

Purpose

The purpose of the ball mill is to grind 1/2 ton per hour of 1/4-inch ore to give a 100-mesh product.

Calculations

The power requirements can be calculated by the method of Bond according to the following equation:

$$W = W_i \sqrt{\frac{100}{P}} \left(\frac{\sqrt{R-1}}{\sqrt{R}} \right),$$

where

W = work input in kwhr/short ton

R = reduction ratio F/P

F = size in microns of the square hole through which 80 per cent of the feed passes

P = size in microns through which 80 per cent of the product passes

W_i = work index in kwhr/short ton, a characteristic of the material.

For ball mills

$$W_i = \left(\frac{16}{G^{0.82}} \right) \sqrt{\frac{P}{100}},$$

where G = grindability in net grams of undersize produced per mill revolution for a 100-mesh product.

$P \approx 149$ microns

$$W_i = \left(\frac{16}{G^{0.82}} \right) \sqrt{\frac{149}{100}} = \frac{19.5}{G^{0.82}}.$$

For La Sal ore $G = 2.4$,

$$W_i = \frac{19.5}{(2.4)^{0.82}} = 9.5$$

$F = 1/4$ inch or 6350 microns

$P = 100$ mesh or 149 microns

$$R = \frac{6350}{149} = 42.6$$

$$W = 9.5 \sqrt{\frac{100}{149}} \left(\frac{\sqrt{42.6-1}}{\sqrt{42.6}} \right) = 6.58 \text{ kwhr/ton ore.}$$

For a feed rate of 12 tons/day or 1/2 ton per hour,

$$\frac{6.58}{2} = 3.29 \text{ kw power requirement or } 4.41 \text{ hp.}$$

From the Denver Equipment Handbook, page 706, the capacity of a 3 x 3-foot ball mill to grind a soft ore from -1/2 inch to pass 28 mesh is 53 tons/day.

The capacity of this mill is inversely proportional to the apertures ground through:

$$53 \left(\frac{0.0058}{0.0234} \right) = 13.1 \text{ tons/day capacity.}$$

A 3 x 3-foot ball is sufficient.

The Denver Equipment Handbook recommends 8-1/2-hp minimum motor size.

Leach Towers (Item 5)

Purpose

The leach towers are for pressure leaching the pulp.

Calculations

Provide capacity for a total of 6 hours' retention time at a throughput of 1000 lb of ore per hour at a pulp density of 50 per cent.

Provide means for heating the pulp from 70 F to 250 F.

Specific gravity of the solids is 2.7. Therefore, the density of a 50 per cent pulp = $\frac{100}{\frac{50}{62.4(2.7)} + \frac{50}{62.4}} = 91 \text{ lb/cu ft.}$

Total required volume of leach towers

$$\frac{24(2000)6}{24(91)} = 132 \text{ cu ft.}$$

If four towers are used in series,

$$\frac{132}{4} = 33 \text{ cu ft per tower.}$$

A section of 16-inch-diameter schedule 40 pipe 25 feet long gives a volume of 30.7 cubic feet. It is undesirable to specify a longer section here because of the headroom limitations. However, the added volume provided by the conical or dome ends will give nearly the 33 cubic feet needed for a 1-1/2 hour retention time per tower.

Heat will be transferred to the pulp by steam in a jacket around the tower. The heat requirements are

$$\begin{array}{rcl}
 1000(1)(250-70) & = & 180,000 \text{ Btu/hr for water} \\
 1000(0.24)(250-70) & = & \underline{43,200 \text{ Btu/hr for solids}} \\
 & & 223,200 \text{ Btu/hr} \\
 \text{Assume Losses} & & \underline{22,000} \\
 & & 245,200 \text{ Btu/hr total heat duty.}
 \end{array}$$

For calculating the heat-transfer area of the jacket the following resistances to heat flow must be considered: R_o = film resistance of condensing steam; R_{do} = dirt film resistance on the steam side; R_w = resistance of metal wall; R_i = film resistance of solution on pulp side; R_{di} = dirt film resistance on pulp side.

In order to calculate the above resistances, the following heat-transfer coefficients were calculated by the appropriate equations

$$h_o = \text{steam film coefficient} = 1000 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(F)}$$

$$h_i = \text{inside liquid film coefficient} = 62.2 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(F)}$$

The assumed dirt or scale resistances are as follows: $R_{do} = 0.0003$; $R_{di} = 0.01$.

$$\text{The conductivity of the metal wall is } 26 \frac{\text{Btu}}{(\text{hr})(\text{ft})(F)}$$

On the basis of outside surface of the tower the resistances are

$$\begin{array}{rcl}
 R_o & = & \frac{1}{1000} = 0.0010 \\
 R_{do} & = & 0.0003 \\
 R_w & = & \frac{0.5(16)}{26(15.5)12} = 0.0016 \\
 R_i & = & \frac{16}{62.2(15)} = 0.0172 \\
 R_{di} & = & 0.01 \left(\frac{16}{15} \right) = \underline{0.0107} \\
 R_{\text{total}} & & = 0.0308 \\
 \text{Over-all } U & = & \frac{1}{0.0308} = 32.5 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(F)}
 \end{array}$$

If steam is available at 100 psig, the temperature difference between the steam jacket and the pulp is $338-250 = 88 \text{ F}$.

The required outside area for heat transfer is

$$\frac{245,200}{32.5(88)} = 85.7 \text{ sq ft.}$$

A 16-inch pipe has 4.189 sq ft per ft length.

$$\text{Length of steam jacket} = \frac{85.7}{4.189} = 20.5 \text{ ft.}$$

The velocity of the pulp through the towers and connecting piping is extremely low, being of the same order of magnitude as in the experimental 4-inch columns. The pulp is expected to remain in suspension because it is already at terminal density. An effort to keep a pulp, which is not at terminal density, in suspension by higher velocity would be futile unless the leaching vessels were redesigned. It would be necessary to effect a change in the velocity by a factor of 50 to 100 to accomplish the turbulence necessary to prevent settling.

Heat Exchanger for Cooling Slurry (Item 6)

Purpose

Two thousand lb/hr of an aqueous slurry 50 per cent solids is to be cooled from 270 F to 110 F by heating 2500 lb/hr of an aqueous ammonium carbonate solution from 90 F to 169 F. About 5 scfm of air may be present with the slurry phase.

Calculations

Information pertinent to the design is:

- (1) Specific gravity of solids in slurry may be assumed to be 2.7.
- (2) Size of solid particles is expected to be minus 100 mesh.
- (3) The bulk of the solids are expected to be varying ratios of limestone and sand.
- (4) The ammonium carbonate solution will contain 1.54 per cent by weight NH_3 and 2.10 per cent by weight CO_2 .
- (5) The slurry side of the exchanger will operate under pressures of 90 to 150 psig.

The duty of the heat exchanger is

$$\begin{aligned} 1000(1)(270-110) &= 160,000 \text{ Btu/hr} \\ 1000(0.24)(270-110) &= \frac{38,400 \text{ Btu/hr}}{198,400 \text{ Btu/hr or}} \end{aligned}$$

round off to 200,000 Btu/hr.

For calculating the heat-transfer area the following resistances to heat flow must be estimated: R_i = film resistance of slurry phase; R_{id} = dirt deposit resistance on slurry side; R_o = film resistance of coolant phase; R_{od} = dirt deposit resistance on coolant side of surface.

The individual liquid-film heat-transfer coefficients were calculated by the Dittus Boelter equation. The equation can be applied to the slurry phase, based upon the properties of the liquid alone except for viscosity. The viscosity was assumed to be ten times that of water. The calculated coefficients are

$$\begin{aligned} h_i &= \text{inside liquid film coefficient} = 216 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(F)} \\ h_o &= \text{outside liquid film coefficient} = 500 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(F)} \end{aligned}$$

The dirt or scale deposit resistances were assumed to be: $R_{id} = 0.007$, $R_{od} = 0.002$.

On the basis of outside area of inside pipe the resistances are as follows:

$$\begin{aligned} R_i &= \frac{1}{216} \left(\frac{1.315}{0.957} \right) = 0.00636 \\ R_o &= \frac{1}{500} = 0.00200 \\ R_{id} &= 0.007 \left(\frac{1.315}{0.957} \right) = 0.00961 \\ R_{od} &= \underline{0.00200} \\ R_{\text{total}} &= 0.01997 \\ \text{Over-all } U &= \frac{1}{0.01997} = 50.0 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(F)} \end{aligned}$$

If the heat exchanger is run countercurrently, the temperature differences at the ends are $270-170 = 100$ F and $110-90 = 20$ F. This gives a log mean temperature difference of

$$\frac{100-20}{2.3 \log \frac{100}{20}} = 49.7 \text{ F}$$

The required area for heat transfer based on outside area of the inside pipe becomes

$$\frac{198,400}{50(49.7)} = 79.9 \text{ sq ft.}$$

A 1-inch pipe has 0.344 sq ft per ft length.

$$\text{Length of pipe required} = \frac{79.9}{0.344} = 232 \text{ ft.}$$

The diameter of the outside pipe is not critical. Either a 1-1/2-inch or 2-inch schedule 40 pipe would be satisfactory.

CCD Thickeners (Item 10)

Purpose

The purpose is to thicken and wash out soluble uranium and ammonia from the pulp.

Calculations

Settling rates obtained from pilot-plant runs are

$$\begin{aligned}\text{No. 1 Thickener} &= 0.43 \text{ ft/hr} \\ \text{No. 2 Thickener} &= 0.542 \text{ ft/hr} \\ \text{No. 3 Thickener} &= 0.985 \text{ ft/hr.}\end{aligned}$$

The area for thickening may be calculated by the equation

$$A = \frac{1.333(F-D)}{R},$$

where: A = area, sq ft/ton - 24 hr

R = settling rate, ft/hr

F = parts water/part of solids in feed

D = parts water/part of solids in underflow.

For thickener No. 1,

$$R = 0.43$$

$$F = \frac{75}{25} = 3$$

$$D = \frac{40}{60} = 2/3$$

$$\text{therefore } A = \frac{1.333(3 - 2/3)}{0.43} = 7.2 \text{ sq ft/ton} - 24 \text{ hr.}$$

$$\text{Total calculated area} = 12(7.2) = 86.5 \text{ sq ft}$$

Allow a 25 per cent safety factor.

$$\text{Area} = 1.25(86.5) = 108 \text{ sq ft}$$

$$\text{Diameter of No. 1 thickener} = 11.7 \text{ ft or } 12 \text{ ft.}$$

The thickener volume may be checked by the equation

$$V = \frac{4T(G - \text{sp gr})}{3G(S - \text{sp gr})},$$

where: T = time for pulp to thicken to discharge solids content
(60 per cent solids)

G = sp gr of solids in pulp

S = average sp gr of thickened pulp during compression period

sp gr = specific gravity of clear solution

V = volume required, cu ft/ton - 24 hr.

From the pilot-plant data T = 16.5 hr. The other variables are: G = 2.7;
S = 1.61; sp gr = 1.0.

$$V = \frac{4(16.5)(2.7-1.0)}{3(2.7)(1.61-1.0)} = 22.7 \text{ cu ft/ton} - 24 \text{ hr.}$$

The total volume required = 22.7 (12) = 272 cu ft. Equivalent depth
of a 12-foot thickener = $\frac{272}{\frac{\pi}{4}(12)^2} = 2.41 \text{ feet.}$

$$\frac{\pi}{4}(12)^2$$

A standard 12-foot-diameter thickener is 8 feet deep and its capacity is, therefore, ample for this purpose.

Thickener Numbers 2, 3, and 4 have faster settling rates than Number 1. Therefore, the 12-foot-diameter size is ample for all stages of the CCD system.

Ammonia-Carbon Dioxide Stripping and Uranium- Precipitating Tower (Item 12)

Purpose

This item is required to drive off the ammonia and carbon dioxide from the pregnant liquor and precipitate the uranium as $\text{UO}_3 \cdot 2\text{H}_2\text{O}$. It is necessary to recover the ammonia distilled off in a reasonably concentrated

solution. It is essential to the economics of the process to design the tower so that the steam requirements are as small as practically possible.

Calculations

It is desired to design a stripping tower which will meet the two following important requirements.

- (1) The steam requirements shall be no greater than 1 pound for each 3 pounds of pregnant solution fed to the tower.
- (2) Approximately 99 per cent of the ammonia is to be recovered in an overhead product of sufficient concentration so as to be suitable for recycling.

Process flowsheets, Figures 2 and 3, show the material balance on the tower which meets these requirements.

The most important calculation for the tower design is the determination of the number of theoretical steps required to give the chosen operating conditions. The actual number of plates are found by dividing the number of theoretical plates by the plate efficiency.

Although the process flowsheet gives material quantities in pounds and weight per cent, it is more convenient to use mols and mol per cent in the analysis of the problem.

Reference to Figure 4 will aid in following the calculations.

FIGURE 4. COLUMN MATERIAL BALANCE

The nomenclature used in the sketch and calculations are defined below.

F = lb mols feed to column
 D = lb mols overhead from column
 S = lb mols steam to bottom plate of column
 W = lb mols bottoms leaving column
 L = lb mols liquid running down column
 V = lb mols vapor passing up through column
 X = mol fraction NH_3 in liquid
 Y = mol fraction NH_3 in vapor
 n and n+1 = designate plates.

By a material balance on the ammonia over the section enclosed by the dotted line between the n and n+1 plates

$$LX_n = VY_{n+1} + WX_w$$

$$Y_{n+1} = \frac{LX_n}{V} - \frac{WX_w}{V};$$

however, $L = W$ and $V = S$, therefore, $Y_{n+1} = \frac{WX_n}{S} - \frac{WX_w}{S}$, which is the

operating line equation. The q line equation is $Y = \left(\frac{q}{q-1} \right) X - \frac{X_F}{q-1}$, where q is defined as the total heat needed to convert one mol of feed into saturated vapor, divided by the molal latent heat.

The equilibrium data is assumed to follow Henry's law for the concentration considered here.

The equilibrium equation is therefore of the form $Y = KX$, where K is the Henry's law constant.

If these three equations are represented on an X-Y plot, the number of theoretical plates may be obtained graphically by the McCabe-Thiele method.

For the basis of the calculation, assume a pregnant solution feed of 100 pound mols/unit of time and of the composition

$\text{NH}_3 = 2.41$ mol per cent
 $\text{CO}_2 = 1.27$ mol per cent
 $\text{H}_2\text{O} = 96.32$ mol per cent

Assuming a solution feed temperature of 170 F gives a value for $q = 1.033$. It can be shown that $W = qF$ or $W = 1.033(100) = 103.3$ mols.

By a material balance on the NH_3 over the entire column $FX_F = DX_D + WX_W$ or $DX_D = FX_F - WX_W$.

Assume $WX_W = 0.03$ mol to give approximately 99 per cent recovery of NH_3 .

Then $DX_D = 100(0.0241) - 0.03 = 2.38$ mols.

Assume $S = 30$ mols to meet steam-consumption requirement

$D + W = S + F$ or $D = S + F - W = 30 + 100 - 103.3 = 26.7$ mols.

Also $X_D = \frac{2.38}{26.7} = 0.0892$ and $X_W = \frac{0.030}{103.3} = 0.000290$.

The stripping-tower flow quantities are then as shown in Figure 5.

FIGURE 5. COLUMN MATERIAL BALANCE

The operating line equation becomes

$$Y_{n+1} = \frac{103.3}{30} X_n - \frac{103.3(0.000290)}{30} \quad \text{or}$$

$$Y_{n+1} = 3.44X_n - 0.000998.$$

The q-line equation becomes

$$Y = \frac{1.033}{0.033} X - \frac{0.0241}{0.033} \quad \text{or}$$

$$Y = 31.3X - 0.730.$$

The equilibrium line equation can be evaluated if the Henry's law constant can be estimated from experimental data. The vapor pressure data from Gmelin's Handbuch der Anorganischen Chemie, Volume 8, page 334, was used to make this estimate. A very conservative K value of 5.5 was estimated. The equilibrium line equation then becomes $Y = 5.5X$.

These three equations are plotted in Figure 6, showing the graphical solution to the number of theoretical plates.

Figure 6 shows that eight theoretical plates are required to give the operating conditions represented on process Flow Plans 2 and 3.

This method of calculation can be used to find the effect of reduced ammonia concentration in the feed on overhead product composition and steam usage. This was done for Process Plan 1, the results of which are shown in the material balance of Figure 1.

Drawing No. 17 shows the type of plate chosen. It is a modified sieve plate with 3/8-inch holes for the liquid. Should the holes plug, the liquid will still overflow the weir and shower down permitting the tower to operate at reasonable efficiency.

The tray efficiency was estimated conservatively to be approximately 27 per cent. On this basis the column requires 30 actual plates.

The column diameter may be estimated by the equation

$$v = 0.135 \sqrt{\frac{\rho_l - \rho_v}{\rho_v}},$$

where v = allowable vapor velocity, ft/sec

ρ_l = density of the liquid = 62 lb/cu ft

ρ_v = density of the vapor = 0.0332 lb/cu ft

$v = 5.85$ ft/sec

$v_{\text{design}} = 0.55(5.85) = 3.22$ ft/sec.

The maximum steam rate of 17,560 lb/day is anticipated for Plan 1. This column should be designed for 50 per cent more than this or for 26,400 lb/day or 9.18 cu ft/sec.

The cross-sectional area giving the maximum allowable vapor velocity then is $\frac{9.18}{3.22} = 2.85$ sq ft.

This corresponds to a column diameter of 1.9 ft.

A 2-foot diameter column is recommended.

Some of the other features of the design are as follows:

- (1) A section below the plates large enough to provide a 1-hour retention time to permit complete precipitation.
- (2) Removable plates with enough manholes for accessibility.

- (3) Sparger for introduction of steam. Live-steam injection aids nucleation of the precipitate.

Condenser (Item 13)

Purpose

It is desired to condense as much as possible of a mixture of vapors consisting of 14,800 lb/day of H_2O , 907 lb/day of NH_3 , and 1279 lb/day of CO_2 . It is also desired to subcool the condensate to at least 100 F and preferably lower in order to retain the maximum amount of NH_3 in solution.

Calculations

The temperature of the vapors to the condenser is about 200 F. It is assumed that cooling water is available at 70 F.

The heat duty of the condenser amounts to about 740,000 Btu/hr.

For calculating the heat-transfer area, the following resistances to heat flow must be estimated; R_i = film resistance of cooling water; R_{id} = dirt deposit resistance on coolant side; R_o = film resistance of condensing vapor; R_{od} = dirt deposit resistance on steam side.

The individual film resistances are estimated to be as follows:

$$h_i = \text{cooling water film coefficient} = 300 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(F)}$$

$$h_o = \text{condensing vapor coefficient} = 1000 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(F)}$$

The dirt or scale-deposit resistances were assumed to be:
 $R_{id} = 0.0012$; $R_{od} = 0.0012$.

The resistances are summarized as follows:

$$R_i = \frac{1}{300} = 0.00333$$

$$R_o = \frac{1}{1000} = 0.00100$$

$$R_{id} = 0.00120$$

$$R_{od} = \frac{0.00120}{0.00673}$$

$$\text{Over-all } U = \frac{1}{0.00673} = 148 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(F)}$$

FIGURE 6. MCCABE-THIELE DIAGRAM FOR ESTIMATION OF NUMBER OF THEORETICAL PLATES IN STEAM STRIPPING COLUMN

The amount of carbon dioxide which will go into solution is unknown and the condensation takes place in the presence of a noncondensable gas. As a result, the above calculation is not strictly correct from a theoretical standpoint. Some crystallization of solids is a possibility but not believed to be serious. As a result of some of these unknown conditions the over-all heat-transfer coefficient was reduced and set at $100 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(\text{F})}$.

Assuming cooling water rising from 70 to 80 F gives temperature differences at the ends of the condenser of: $80-70 = 10 \text{ F}$; $200-80 = 120 \text{ F}$. The log mean temperature difference is then

$$\frac{120-10}{2.3 \log \frac{120}{10}} = 44.3 \text{ F.}$$

The required area for heat transfer then is

$$\frac{740,000}{100(44.3)} = 167 \text{ sq ft.}$$

Heat Exchanger (Item 16)

Purpose

It is desired to be able to cool approximately 23,000 lb/day of aqueous solution from 100 F to 80 F with cooling water at 70 F.

Calculations

A double-pipe heat exchanger designed for a duty of about 20,000 Btu/hr is required.

The condensate can be put through a 1/2-inch inside pipe and the cooling water through the annulus.

For calculating the heat-transfer area, the following resistances must be estimated: R_i = inside liquid film resistance; R_o = outside liquid film resistance; R_{id} and R_{od} = inside and outside dirt-deposit resistances.

The individual liquid-film heat-transfer coefficients are estimated to be

$$h_i = \text{inside liquid-film coefficient} = 600 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(\text{F})}$$

$$h_o = \text{outside liquid-film coefficient} = 600 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(\text{F})}$$

The dirt-deposit resistances should be small and are taken as 0.0012.

The resistances may be added as follows:

$$\begin{aligned}
 R_i &= \frac{0.840}{0.622} \frac{1}{600} = 0.00226 \\
 R_o &= \frac{1}{600} = 0.00167 \\
 R_{id} &= \frac{0.840}{0.622} \cdot 0.0012 = 0.00162 \\
 R_{od} &= \underline{0.00120} \\
 R_{total} &= 0.00675
 \end{aligned}$$

$$\text{The over-all heat transfer coefficient } U = \frac{1}{0.00675} = 150 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(\text{F})}$$

is based on the outside area of the inside pipe.

If the exchanger is run countercurrently with cooling water going from 70 F to 80 F, the temperature differences at the ends are: $100-80 = 20$ F; $80-70 = 10$ F. The log mean temperature difference is therefore

$$\frac{20-10}{2.3 \log \frac{20}{10}} = 14.4 \text{ F.}$$

The heat-transfer area required is

$$\frac{20,000}{14.4(150)} = 9.3 \text{ sq ft.}$$

Approximately 50 feet of 1/2-inch pipe providing 11 square feet is recommended.

Carbon Dioxide Absorption Tower (Item 17)

Design data for the absorption of carbon dioxide in NH_4OH solutions are not available in any known published literature. Therefore, some assumptions and approximations will have to be made in calculating the tower height. These approximations will be made so that the design is conservative and the resulting tower height somewhat larger than necessary.

For the case of absorbing CO_2 from an inert gas stream and where the concentration of CO_2 in the gas stream is low, the following equation can be used.

$$h = \frac{M}{K_{ga} (p-p_e) \log \text{mean}},$$

where h = height of tower packing

M = lb-mols of gas absorbed in tower/sq ft cross section

K_{ga} = mass-transfer coefficient of CO_2 in NH_4OH , $\frac{\text{lb-mols}}{(\text{hr})(\text{cu ft})(\text{atm})}$

p = partial pressure of CO_2 in inert gas stream, atm

p_e = vapor pressure of CO_2 over the NH_4OH solution.

This simplified equation for lean gas mixtures results because it can be assumed that K_{ga} , $(p-p_e)$ and the equilibrium curve are linear over the range encountered.

A study of the absorption of carbon dioxide in NaOH or KOH solutions led to the following conclusions.

(1) Chemical reaction rate and rate of diffusion of carbon dioxide through the liquid film are of the same order of magnitude and both control the over-all rate of carbon dioxide absorption.

(2) K_{ga} is only slightly affected by the gas velocity in the tower.

Although no experimental data on the absorption of carbon dioxide in NH_4OH solutions have been published, it would be expected to behave similarly to absorption of carbon dioxide in NaOH or KOH , but probably at a different rate.

Since pure carbon dioxide with no inert gas is to be used for the make-up carbon dioxide source, the value of p will remain constant at about 1.0 atmosphere. This results in a very small difference between the value of $(p-p_e)$ at top and bottom of the tower.

Since the value of K_{ga} is little affected by change in gas velocity due to the absorption, an average value of K_{ga} can be used.

On the basis of the above reasoning the lean gas equation can be used to give an order of magnitude value:

$$M = \frac{1555}{24(44)} = 1.47 \frac{\text{lb-mols}}{(\text{hr})(\text{sq ft})}$$

$$(p-p_e) \text{ at top of tower} = 1.00 \text{ atm}$$

$$(p-p_e) \text{ at bottom of tower} = 1.00 - 0.032 = 0.968 \text{ atm}$$

$$\text{Average } (p-p_e) = 0.984 \text{ atm.}$$

A value of K_{ga} of 0.30 was selected by an inspection of K_{ga} values for carbon dioxide absorption in NaOH , KOH , and amine solution. The value taken is considerably lower than those of the experimental data.

Therefore,

$$h = \frac{1.47}{0.30(0.984)} = 4.98 \text{ ft.}$$

Due to the many unknowns involved, such as variations in solution concentrations, temperatures, etc., and to provide flexibility, a packed height of 10 feet is recommended.

Since the liquid film is one of the controlling resistances to the absorption, a reasonably high liquid rate should be obtained. A 14-inch-diameter column should provide a satisfactory liquid velocity even if the flow quantities are changed by twofold.

ARVK:RDM:FMS/dlw

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APPENDIX A

EQUIPMENT SPECIFICATIONS

APPENDIX A

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EQUIPMENT SPECIFICATIONS

Item 1 - Ball Mill

A 3-foot-diameter x 2-foot ball mill is already in place in the alkaline leach plant at Grand Junction.

Otherwise use a 3-foot-diameter x 3-foot ball mill with a minimum motor size of 10 hp.

Item 2 - Rake Classifier

A 1-foot 6-inch by 13-foot Dorr rake classifier is already in place in the alkaline leach plant at Grand Junction. This machine should be adequate.

Item 3 - Thickener

Either the 12-foot or 18-foot thickener present in the alkaline leach plant is satisfactory if properly covered.

Item 4 - Pump Box

Approximately 50 gal capacity. A cylindrical tank 1-1/2-feet in diameter x 3 feet plus a 60-degree conical bottom. The top rim of the tank should be flanged for a bolt-on gasketed cover.

A 1-1/2-inch pipe nipple should be provided at bottom of cone for the pulp outlet. Two 1-1/2-inch pipe nipples should be installed in the cover, one for pulp inlet and one for pulp recirculation. A tapped hole in the cover to receive a 1/4-inch pipe should be made for the vent.

Another opening in the cover will be required for a float-type level indicator. This can be done after selection of the float mechanism.

Mild steel construction is recommended.

Item 5 - Leach Towers

The leach towers are specified in detail by Drawing Nos. 1 through 8 in Appendix B.

Item 6 - Heat Exchanger

A double pipe heat exchanger is recommended for this application.

The heating duty is approximately 200,000 Btu/hr. The over-all heat-transfer coefficient is estimated to vary from $85 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(\text{F})}$ when clean to $50 \frac{\text{Btu}}{(\text{hr})(\text{sq ft})(\text{F})}$ after a period of operation. The required area based upon the lower value is 80 sq ft (outside area of inside pipe).

It is proposed to put the slurry through the inside pipe and the solution through the annular space.

A 1-inch schedule 80 pipe is recommended for the inside pipe. This size is selected as a compromise to provide sufficient velocity for good heat transfer but still low enough to reduce attrition by the solids. The extra thickness is specified from the standpoint of abrasion rather than pressure. Either a 1-1/2-inch or 2-inch schedule 40 pipe would be satisfactory for the outside pipe.

Based on 80 sq ft of surface, the total effective length of 1-inch pipe is 233 ft. If the exchangers are assembled in 15-ft effective lengths, 16 lengths are required. The exchanger can be made up of hairpin units consisting of two legs each. Eight such units would be required.

It is essential that the return bends be removable rather than welded. Maximum radius bends are recommended.

Item 7 - Gas-Liquid Separator

See Drawing Nos. 9, 10, 11, and 12 of Appendix B. The air-pulp mixture enters tangentially to reduce splashing. The low gas velocity in the 12-inch pipe and the distance from gas inlet to outlet causes entrained liquid and solids to drop out. It is recommended that a Magnetrol level control Model A-100-F be mounted in the top to control the level between positions 11 inches apart by activating a solenoid valve on the pulp discharge.

Item 8 - Surge Tank

Approximately 150 gal capacity. A cylindrical tank 2-1/2 ft diameter x 3-1/2 ft plus a 60-degree conical bottom. The top rim of the tank should be flanged for a bolt-on gasketed cover.

A 1-1/2-inch pipe nipple should be provided at bottom of the cone for the pulp outlet. Two 1-1/2-inch pipe nipples should be installed in the cover, one for pulp inlet and one for pulp recirculation. A tapped hole in the cover to receive a 1/4-inch pipe should be made for the vent.

Another opening in the cover will be required for a float type indicator. This can be done after selection of the float mechanism.

Mild steel construction is recommended.

Item 9 - Thickener Mix Tanks

Approximately 25 gal capacity. A cylindrical tank 1-1/2 ft diameter x 2 feet with flat bottom or very shallow angle cone if desired to facilitate cleaning. The top rim of the tank should be flanged for a bolt-on gasketed cover.

A 1-1/2-inch pipe nipple should be provided at the center in the bottom for cleaning and draining. A 1-1/2-inch pipe nipple should be installed in the side of the tank about 18 inches from the bottom for the overflow outlet. Two 1-1/2-inch pipe nipples should be installed in the cover for the two incoming streams. A tapped hole in the cover to receive a 1/4-inch pipe should be made for the vent.

Agitation should be provided by means of a top-mounted propeller agitator such as 1/2-hp Lightning or Eastern mixer.

Mild steel construction is recommended.

Four tanks of these specifications are required.

Item 10 - Thickeners

Four 12-foot-diameter thickeners set up for CCD operation. Thickeners present in acid plant are adequate if properly covered.

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Item 11 - Surge Tank

Approximately 400 gal capacity. A cylindrical tank 4 foot diameter x 4-1/2 feet with flat bottom or very shallow angle cone if desired to facilitate cleaning. The top rim of the tank should be flanged for bolt-on gasketed cover.

A 1-inch pipe nipple should be provided at the center in the bottom for the liquor outlet. A 1-inch pipe nipple should be installed in the cover for the liquor outlet. A tapped hole in the cover to receive a 1/4-inch pipe should be made for a vent.

A sight-glass level indicator along the side of the tank is recommended.

Mild steel construction is recommended.

Item 12 - CO₂ and NH₃ Stripping Tower

Drawings 14, 15, 16, 17, 18, and 19 of Appendix B show the mechanical design of the tower.

Item 13 - Condenser

A shell and tube condenser is recommended. The choice of passing the vapors into the tubes or shell should be left to the manufacturer.

The condenser should be capable of removing 740,000 Btu/hr.

A minimum heat transfer area of 167 sq ft is recommended.

The mechanical design of the condenser and location of vent for non-condensed CO₂ are important. The arrangement should be such that a minimum loss of NH₃ with vented CO₂ results.

Item 14 - Accumulator and NH₃ Absorption Tank

Approximately 65 gal capacity. A cylindrical tank 1-1/2 feet in diameter by 5 feet with flat bottom or very shallow angle cone if desired to facilitate cleaning. It is essential to provide a liquid depth of 3 or 4 feet to insure complete NH₃ absorption.

The top rim of the tank should be flanged for a bolt-on gasketed cover.

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A 1-inch pipe nipple should be installed in the side of the tank about 3 inches from the bottom for the NH_3 inlet. A 1-inch pipe nipple should be installed in the side of the tank about 4 feet from the bottom for the overflow outlet. A 1-inch pipe nipple should be installed at the center in the bottom of the tank for a drain.

Three 1-inch pipe nipples should be installed in the cover for liquor inlet, makeup water inlet, and gas vent.

Mild steel construction is recommended.

Item 15 - Surge Tank

Approximately 150 gal capacity. A cylindrical tank 2-1/2 feet in diameter x 4 feet with flat bottom or very shallow angle cone if desired to facilitate cleaning.

The top rim of the tank should be flanged for a bolt-on gasketed cover.

A 1-inch pipe nipple should be installed in the center of the bottom for the liquor outlet. A 1-inch pipe nipple should be installed in the cover for the liquor inlet. A tapped hole in the cover should be made to receive a 1/4-inch pipe for the vent.

A sight-glass level gage along the side of the tank is recommended.

Mild steel construction is recommended.

Item 16 - Heat Exchanger

A double pipe heat exchanger is recommended.

The heating duty is approximately 20,000 Btu/hr. Assuming cooling water going from 70 F to 80 F results in a required area of 11 sq ft (outside area of inside pipe).

It is proposed to put the condensate through the inside pipe and the cooling water through the annular space.

A 1-1/2-inch pipe is recommended for the inside pipe and either a 1-inch or 1-1/4-inch pipe would be satisfactory for the outside pipe.

Approximately 50 ft of 1/2-inch pipe are required to provide the 11 sq ft of heat-transfer area. The exchanger can be a welded double-pipe type and the return bends need not be removable, since it should not be necessary to take apart for cleaning.

It would be desirable to assemble the exchanger in 10-foot effective lengths.

Item 17 - CO₂ Absorption Tower

Drawing Nos. 21, 22, and 23 of Appendix B show the mechanical design of the tower.

Item 18 - Pump Box

Approximately 50 gal capacity. A cylindrical tank 2 feet in diameter x 2 feet with flat bottom or very shallow cone. Top rim of tank should be flanged for a bolt-on gasketed cover.

A 1-inch pipe nipple should be installed in the center of the bottom for the liquor outlet. A 1-inch pipe nipple should be installed in the cover for liquor inlet. A tapped hole should be made in the cover to receive a 1/4-inch pipe for the vent and a sight-glass level gage provided along the side of the tank.

Mild steel construction is recommended.

Item 19 - Regenerated Solution Storage

Approximately 1000 gal capacity. A cylindrical tank 5 feet in diameter x 7 feet with flat bottom or very shallow angle cone, if desired, to facilitate cleaning.

The top rim of the tank should be flanged for a bolt-on gasketed cover.

A 1-inch pipe nipple should be installed in the center of the bottom and a similar one in the cover. A tapped hole for receiving a 1/4-inch pipe should be made in the cover for a vent and a sight-glass level gage provided along the side of the tank.

Mild steel construction is recommended.

Item 20 - Precipitated Solution Storage

Use one of tanks on filter floor of alkaline leach plant.

Item 21 - Alum Solution Storage

Approximately 200 gal capacity. A cylindrical tank 3 feet in diameter x 4 feet with flat bottom or very shallow cone. No cover required.

Tank can be air or propeller agitated. A 1/4-hp Lightning mixer or equivalent would be adequate.

A 1-inch pipe nipple should be installed in the center of the bottom.

Item 22 - Filter Press

One of the filters present in alkaline pilot plant is adequate.

Item 5A - Drum Filter

Approximately 14 sq ft of filter area are required. A 3 foot diameter x 2 feet rotary vacuum filter would be adequate for ores other than Cal uranium.

Filterability tests on Cal uranium ores indicate a tenfold increase in filter area requirements over La Sal or black limestone. Rather than specifying a larger filter here, it would be advisable to try the addition of flocculants to aid the filtration.

The following equipment, Items 1A through 4A, make up the dry-grinding circuit. With the exception of Item 4A, they are as specified by the Hardinge Company of York, Pennsylvania.

Item 1A - Constant-Weight Feeder for Dry Ball Mill

Size "A" Hardinge constant-weight feeder, complete with rubber belt, revolution indicator, no-load cut-off contactor, speed reducer, 3-phase 60-cycle 220/440-volt totally enclosed motor, all mounted on pivoted frame suspended from feed hopper and including feed hopper with flange for bolting to supply bin outlet.

Item 2A - Conical Ball Mill and Auxiliaries for Dry Grinding

- (a) 4-1/2-foot-diameter x 16-inch cylinder-length Hardinge conical ball mill, complete with shell, trunnions, bearings, gearing, feeder, and lining, all specified as follows: Meehanite cast steel shell, having 13-inch-diameter x 10-inch-long integral trunnions, babbitted ball-and-socket-type main bearings with baseplates, Meehanite cast tooth spur gear, 94 teeth, 2-inch CP, 5-inch face, with 17 teeth forged steel pinion, 2-15/16-inch-diameter countershaft with three ring oiling countershaft bearings with baseplates, 24-inch conical feeder, discharge arrangement suitable for connection to an air-classifying system, and one complete set of lining consisting of Ni-Hard liner plates with chromium steel wedge bars, and including nuts, bolts, and washers for installing in mill.
- (b) V-belt drive, consisting of one 7.0-inch-pitch-diameter motor sheave, one 38-inch-pitch-diameter countershaft sheave, and nine B158S Gates Super-Vulco V-belts, arranged to operate on approximately 41.5-inch center distance.
- (c) 20-hp Westinghouse or equal, high-torque squirrel-cage motor, NEMA Type "C", open type, 870 rpm, with slide base.

Item 3A - Air-Classifier System and Auxiliaries
for Dry-Grinding Circuit

- (a) No. 24 gyrotor air-classifier system, complete with exhaust and V-belt drive, finished product collector and sufficient piping to locate collector discharge up to 30 feet above mill center line; also including drive and motor for gyrotor, but not including fan motor nor filter system for vent.
- (b) Model D-36-4 disk-type Aeroturn dust collector, complete with exhaust fan and motor.
- (c) 3-hp 1750-rpm Westinghouse or equal squirrel-cage normal-torque motor, open type, with slide base, for 3-phase 60-cycle 220/440-volt current.

Item 4A - Mixing Tank

Approximately 85 gal capacity. A cylindrical tank 2 feet in diameter x 3 feet plus 60-degree conical bottom. The top rim of the tank should be flanged for a bolt-on gasketed cover.

A 1-1/2-inch pipe nipple should be provided at the bottom of the cone for the pulp outlet. Another 1-1/2-inch pipe nipple should be installed in the cover for pulp recirculation. A tapped hole in the cover to receive a 1/4-inch pipe should be made for the vent. Other openings in the cover will be required for the ore inlet and float-type level-indicator mechanism.

Mild steel construction is recommended.

Pumps

All pumps will be handling ammoniacal solutions; therefore, no brass or copper may be used for any of the wetted parts.

P-1. Classifier Overflow

This pump is already installed in the alkaline pilot plant.

P-2. Thickener Underflow Pump

This pump is already installed in the alkaline pilot plant.

P-3. Supply Pump

This pump will insure a continuous supply to the suction of the pressure leach feed pump and recirculate to the pump box, Item 4. Flow at design rate will be 2000 lb/hr of 50 per cent solids slurry (90 lb/cu ft) plus whatever recirculation rate is needed. A diaphragm pump similar to a Number 1-1/2 O.D.S. is recommended.

P-4. Pulp Feed Pump for Pressure Leach

The pumping problem here is a difficult one and it is believed that a certain amount of trouble may be encountered regardless of the choice of pump. Therefore, it is strongly recommended that a standby pump be installed. It is further recommended that the two pumps be of different designs so as to provide operating experience.

The pumping requirements are 2000 lb/hr of 50 per cent solids slurry (90 lb/cu ft) and pressures from 100-250 psi. A Milton Roy pump capable of the above capacity and 300 psi is recommended for the feed pump. A Shriver diaphragm pump of maximum pressure is recommended for the standby pump.

Both pumps should be specified to have hard balls and seats such as high-alumina ceramics as first choice, followed by Stellite or tungsten carbide as alternate choices.

P-5. Pulp-Transfer Pump

This pump will transfer approximately 2000 lb/hr of 50 per cent solids slurry (90 lb/cu ft) from the alkaline plant to the CCD system in the acid plant. Approximate distance of transfer is 160 feet. A diaphragm pump similar to a Number 1-1/2 O.D.S. pump is recommended.

P-6. Thickener Underflow Pumps

These pumps are already installed in the CCD system in the acid plant.

P-7. Pregnant-Solution Feed Pump to Stripping Tower

This pump will supply the head to deliver 2500 lb/hr of solution (62 lb/cu ft) through the heat exchanger, Item 6, and to the top of the stripping tower, Item 12. The pressure drop through the heat exchanger will depend upon the particular design selected but would be expected to be in the range of 10-20 psi. A fluid head of 50 ft or 22 psi may be required for the delivery to the top of the stripping tower. A total pressure drop of about 50 psig may be expected. It may be desirable to use two pumps, one before the heat exchanger and one after. A centrifugal type pump is recommended. It is suggested that Eastern multistage centrifugal pumps (Models 2F, 2J, 3F, 3J) be considered since they are designed for low flow rates and high pressure.

P-8. Precipitated-Solution Transfer Pump

This pump will transfer approximately 2500 lb/hr of solution (62 lb/cu ft) from the stripping tower, Item 12, to storage tank, Item 20. A total pressure drop of approximately 15 psi may be expected. Solids to the extent of 0.2 per cent may be expected. A centrifugal-type pump is recommended. The same model numbers are suggested as recommended for P-7.

P-9. Feed-Liquor Pump to Carbonation Tower

This pump will deliver approximately 1000 lb/hr of solution (62 lb/cu ft) from the surge tank, Item 15, through the heat exchanger, Item 16, to the top of the carbonation tower, Item 17. A pressure drop through the heat exchanger of approximately 5 psi may be expected. A total pressure drop of 20 psi may be expected. A centrifugal-type pump is recommended. The same model numbers are suggested as recommended for P-7.

P-10. Regenerated-Solution Transfer Pump

This pump will deliver approximately 1000 lb/hr of solution (62 lb/cu ft) from the pump box, Item 18, to the storage tank, Item 19. A total pressure drop of 15 psi may be expected. A centrifugal-type pump is recommended. The same model numbers are recommended as for P-7.

P-11. Pressure-Filter Feed Pump

This pump is probably already installed in the alkaline leach plant.

P-12. Tailings Pump

This pump will transfer approximately 1500 lb/hr of 60 per cent solids slurry (100 lb/cu ft) from the alkaline plant to tailings disposal. This pump is already in place in the carbonate plant.

47

APPENDIX B

EQUIPMENT DRAWINGS AND PLANT LAYOUT

[illegible]

49

50

FRACTIONAL DIMENSIONS			
SCALE		DATE	
1-10-56		DRAWN BY	
J.L.C.		CHECKED BY	
SHOP ORDER NO.		PROJECT NO.	
6-2392		DRAWING NO.	
1			
REV	LET	REVISIONS	NAME DATE

10" socket-type
welding flange
150 lb st'd

$6 \times \frac{1}{2} \times 17 \frac{3}{4}$
16 req'd
See Note 3

$\frac{1}{8}$ " drill, 32 holes
Note: Dimensions are
symmetrical about
centerlines.

- Note: 1. All corner and tee joints are $\frac{1}{2}$ " fillet welded on both sides.
2. All butt joints beveled and welded both sides.
3. Corner flange braces are to be fillet welded at ends and to underside of top flange.
4. Leg bearing surfaces on underside of frame are to be ground flush before welding legs to frame.
5. All welds on top surface ground flush before welding pipe flange in place.

Est. weight - 2600 lb

FRACTIONAL DIMENSIONS ±			
SCALE	BATTTELLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO		
DATE	12-28-55	BASE OF LEACHING TOWERS	
DRAWN BY	J.L.C.	PROJECT NO.	6-2392
CHECKED BY		DRAWING NO.	3
SHOP ORDER NO.			
REV	REVISIONS	NAME	DATE
LET			

55

56

Note: The angular position of the $1\frac{1}{2}$ " nipples and the $\frac{3}{4}$ " pipe tapped holes may be changed to facilitate piping.

Material: Steel, 0.35 max carbon
4 req'd

				SCALE $1'' = 1''$ $\frac{1}{4}'' = 1''$		FRACTIONAL DIMENSIONS ± BATTELLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO	
				DATE -5-56		BOTTOM SECTION OF LEACHING TOWER	
				DRAWN BY J.L.C.			
				CHECKED BY			
				SHOP ORDER NO		DRAWING NO	
REV REVISIONS NAME DATE				PROJECT NO 6-2392		5

Material: Steel, 0.35 max carbon
8 req'd

				FRACTIONAL DIMENSIONS *	
				SCALE	BATTELLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO
				DATE	
				DRAWN BY	
				CHECKED BY	MID OR TOP SECTION LEACHING TOWER
				SHOP ORDER NO	
REV	REVISIONS	NAME	DATE	PROJECT NO	DRAWING NO
				G-2392	6

No. req'd:
4 at the top
4 at the bottom

FRACTIONAL DIMENSIONS ±			
REV.	LET.	REVISIONS	SCALE
			DATE
			DRAWN BY
			CHECKED BY
REV.	LET.	REVISIONS	MAT'L
			PROJECT NO.
			DRAWING NO.

BATTTELLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO	
CAP, LEACHING TOWER	
G-2392	7

61

62

Material: Steel, 0.35 max. carbon
 4 req'd

FRACTIONAL DIMENSIONS ±			
SCALE		DATE	
DATE		DRAWN BY	
DRAWN BY		CHECKED BY	
CHECKED BY		PROJECT NO	
PROJECT NO		DRAWING NO	
DRAWING NO		REV	
REV		REVISIONS	
REVISIONS		NAME	
NAME		DATE	
DATE		MAT'L	
MAT'L		6-2392	
6-2392		8	

Drawing No. 12

Drawing No. 11

Drawing No. 10

FRACTIONAL DIMENSIONS ±

				SCALE 3/16" = 1"	BATTELLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO	
				DATE 1-31-56		
				DRAWN BY J. L. C.	GAS-LIQUID SEPARATOR	
				CHECKED BY		
				SHOP ORDER NO.	PROJECT NO.	DRAWING NO.
REV. LET.	REVISIONS	NAME	DATE		G-2392	9

1 req'd

FRACTIONAL DIMENSIONS ±

				SCALE 1/4" = 1"	BATTELLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO	
				DATE 1-30-56		
				DRAWN BY J.L.C.	CONICAL HEAD GAS - LIQUID SEPARATOR	
				CHECKED BY		
				SHOP ORDER NO.	PROJECT NO. G-2392	DRAWING NO. 10
REV LET	REVISIONS	NAME	DATE			

67

68

1 req'd

FRACTIONAL DIMENSIONS $\pm$

				SCALE	BATTELLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO	
				DATE 1-30-56		
				DRAWN BY J.L.C.	BODY GAS - LIQUID SEPARATOR	
				CHECKED BY		
				SHOP ORDER NO.	PROJECT NO. G-2392	DRAWING NO. 11
REV LET	REVISIONS	NAME	DATE

3" pipe, Schedule 40

3" 150-lb slip-on flange

3" x 20 1/2" 300-lb reducing flange

1 req'd

FRACTIONAL DIMENSIONS ±

				SCALE 1/4" = 1"	BATTELLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO	
				DATE 1-31-56		
				DRAWN BY J.L.C.	HEAD GAS-LIQUID SEPARATOR	
				CHECKED BY		
				SHOP ORDER NO.	PROJECT NO.	DRAWING NO.
REV	REVISIONS	NAME	DATE		G-2392	12

SCALE	BATTELLE MEMORIAL INSTITUTE
DATE	MECHANICAL ENGINEERING DIVISION
DRAWN BY	COLUMBUS, OHIO
CHECKED BY	EQUIPMENT LAYOUT
MAT'L	AMMONIUM CARBONATE LEACH
PROJECT NO.	DRAWING NO.
G-2392	13A

Equipment For Ammonium Carbonate Leach Process

1. Ball mill (see other views)	12. NH_3 - CO_2 stripping and precipitating tower
2. Rake classifier (see other views)	13. Condenser
3. Thickener (grinding circuit)	14. Accumulator and NH_3 absorption tank
4. Pump box	15. Surge tank
5. Leach towers	16. Heat exchanger (condensate cooler)
6. Heat exchanger (slurry cooler)	17. CO_2 absorption tower
7. Gas-liquid separator	18. Pump box
8. Surge tank	19. Regenerated solution storage
9. Thickener mix (in acid plant)	20. Precipitated solution storage
10. Thickeners CCD (in acid plant)	21. Alum solution storage
11. Surge tank	22. Filter press

West Elevation

FRACTIONAL DIMENSIONS ±			
SCALE		BATTTELLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO	
DATE		AMMON. CARB. LEACH EQUIPMENT LAYOUT	
DRAWN BY		SHOP ORDER NO	PROJECT NO
CHECKED BY		6 2392	13 B
REV	REVISIONS	NAME	DATE
LET			

Equipment for Ammonium Carbonate Leach Process

1. Ball mill	12. $\text{NH}_3\text{-CO}_2$ stripping and precipitating tower
2. Rake classifier	13. Condenser
3. Thickener (grinding circuit)	14. Accumulator and NH_3 absorption tank
4. Pump box	15. Surge tank
5. Leach towers	16. Heat exchanger (condensate cooler)
6. Heat exchanger (slurry cooler)	17. CO_2 absorption tower
7. Gas-liquid separator (see other views)	18. Pump box
8. Surge tank (see other views)	19. Regenerated solution storage
9. Thickener mix tanks (in acid plant)	20. Precipitated solution storage
10. Thickeners, CCD (in acid plant)	21. Alum solution storage
11. Surge tank	22. Filter press

South Elevation

FRACTIONAL DIMENSIONS ±			
SCALE		BATTTELLE MEMORIAL INSTITUTE	
DATE 2-14-56		MECHANICAL ENGINEERING DIVISION	
DRAWN BY J.L.C.		COLUMBUS, OHIO	
CHECKED BY		AMMON. CARB. LEACH	
SHOP ORDER NO.		EQUIPMENT LAYOUT	
PROJECT NO.		DRAWING NO.	
6-2392		13C	
REV	REVISIONS	NAME	DATE
LET

Details of Base Plates and Hole Spacing

Legs are braced on all 4 sides, only 2 shown.

1 1/2" pipe
8 pieces
between flanges

12 WF 50

5/8" mach. bolts

4x4x1/2 angle

8 WF 35

- Note:
1. Butt joint beveled and welded both sides.
 2. Welds on top surface ground flush.
 3. Legs are 1/4" fillet welded all around to base plates and to square structure.
 4. 1 1/2" pipe welded all around both ends between flanges.

1 req'd

FRACTIONAL DIMENSIONS 2			
SCALE	DATE	BATTTELLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO	
DRAWN BY	2-27-55	BASE -	
CHECKED BY	J.L.C.	STRIPPING TOWER	
SHOP ORDER NO.	PROJECT NO.	DRAWING NO.	
	6 2392	14	
REV	REVISIONS	NAME	DATE
LET

Material: Steel
1 req'd

					SCALE	AS NOTED		BATTELLE MEMORIAL INSTITUTE	
					DATE	2-29-56		MECHANICAL ENGINEERING DIVISION	
					DRAWN BY	J.L.C.		COLUMBUS, OHIO	
					CHECKED BY			LOWER SECTION	
								STRIPPING TOWER	
					SHOP ORDER NO.			PROJECT NO.	DRAWING NO.
								6-2392	15
REV.	REVISIONS			NAME	DATE

Section A-A

Scale: $\frac{1}{8}'' = 1''$

Detail of Upper Part

Scale: $\frac{1}{8}'' = 1''$ Scale: $\frac{3}{4}'' = 1' - 0''$

REV LET	REVISIONS	NAME	DATE	MAT'L	PROJECT NO.	DRAWING NO.
				Steel	G-2392	16
As noted				BATTLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO		
3-2-56				UPPER SECTION - STRIPPING TOWER		
J.L.C.						
CHECKED BY						

FRACTIONAL DIMENSIONS ±

5 x 2 extra-strong reducer
cut off to fit cone

Mat'l: Steel
1 req'd

FRACTIONAL DIMENSIONS ±

				SCALE 1/8" = 1"	BATTELLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO	
				DATE 3-1-56		
				DRAWN BY J.L.C.	BOTTOM CAP STRIPPING TOWER	
				CHECKED BY		
				SHOP ORDER NO.	PROJECT NO. G-2392	DRAWING NO. 18
REV. LET.	REVISIONS	NAME	DATE

Mat'l: Steel
1 req'd

FRACTIONAL DIMENSIONS $\pm$

				SCALE 1/8" = 1"	BATTELLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO	
				DATE 3-5-56		
				DRAWN BY J.L.C.	SPARGER	
				CHECKED BY		
				SHOP ORDER NO.	PROJECT NO. G-2392	DRAWING NO. 19
REV. LET.	REVISIONS		NAME	DATE

FRACTIONAL DIMENSIONS ±				DATE	
SCALE				3-6-56	
DATE				JLC	
DRAWN BY				JLC	
CHECKED BY					
MATERIAL				PROJECT NO.	
				G-2392	
				DRAWING NO.	
				20	
				STRIPPING TOWER	
				BATTELLE MEMORIAL INSTITUTE	
				MECHANICAL ENGINEERING DIVISION	
				COLUMBUS, OHIO	
				REV	
				LET	
				REVISIONS	
				NAME	
				DATE

FRACTIONAL DIMENSIONS $\pm$

Note:

Clamp bars and angles securely in place before welding.
Weld ends of bars to semicircular band with a fillet weld.
Tack angles at 3 places on top and bottom.

Mat'l: Steel
2 req'd

REV.	LET.	REVISIONS	NAME	DATE

SCALE 1/2" = 1"
DATE 3-7-56
DRAWN BY J.L.C.
CHECKED BY
SHOP ORDER NO.

FRACTIONAL DIMENSIONS ±		
BATTELLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO		
GRATE CO ₂ ABSORPTION TOWER		
PROJECT NO. G-2392	DRAWING NO. 22

FRACTIONAL DIMENSIONS $\pm$

REV. LET.	REVISIONS	NAME	DATE	SCALE $\frac{3}{8}'' = 1''$	BATTELLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO	
				DATE 3-10-56		
				DRAWN BY J. L. C.	DISTRIBUTOR CO ₂ ABSORPTION TOWER	
				CHECKED BY		
				SHOP ORDER NO.	PROJECT NO. G-2392	DRAWING NO. 23

Note: Steam and air line systems go to all 4 towers similarly to those shown on this sketch.

A single air rotameter and steam trap are adequate to service all 4 towers.

A - 1 $\frac{1}{2}$ " pinch-type flexible rubber valve
B - 1 $\frac{1}{2}$ " Grinnell-Saunders diaphragm valve or equal
C - Same as B except 2"
D - 2" Nordstrom lubricated plug valve or equal
E - 1 $\frac{1}{2}$ " gate valve
F - 1 $\frac{1}{2}$ " globe valve
G - 1 $\frac{1}{2}$ " check valve
H - 1 $\frac{1}{2}$ " globe valve

Item No.	Equipment
1	Ball mill
2	Rake classifier
3	Thickener
4	Pump box
5	Leach towers
6	Heat exchanger
7	Gas-liquid separator
8	Surge tank
9	Thickener mix tanks
10	Thickeners
11	Surge tank
12	$\text{NH}_3\text{-CO}_2$ stripping and precipitating tower
13	Condenser
14	Accumulator and NH_3 absorption tank
15	Surge tank
16	Heat exchanger
17	CO_2 absorption tower
18	Pump box
19	Regenerated solution storage
20	Precipitated solution storage
21	Alum solution storage
22	Filter press
P-1	Classifier overflow pump
P-2	Thickener underflow pump
P-3	Pulp supply pump
P-4	Pulp feed to pressure leach pump
P-5	Pulp transfer pump
P-6	Thickener underflow pump
P-7	Pregnant solution feed to Item 12 pump
P-8	Precipitate transfer pump
P-9	Feed liquor to carbonation pump
P-10	Regenerated solution transfer pump
P-11	Pressure filter feed pump

This drawing is not intended to be a complete detailed piping plan. It shows line sizes and important valves. Additional lines and valves may be added in the field depending on final equipment locations.

				FRACTIONAL DIMENSIONS ±	
				SCALE	BATTELLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO
				DATE	
				DRAWN BY A.V.K	
				CHECKED BY	
				SHOP ORDER NO	PROJECT NO
				SCHEMATIC PIPING DIAGRAM FOR AMMONIUM CARBONATE LEACH PILOT PLANT	
REV	REVISIONS		NAME	DATE	G-2392 24A

- 1 Ball mill
- 2 Rake classifier
- 3 Thickener
- 4 Pump box
- 5 Leach towers
- 6 Heat exchanger
- 7 Gas-liquid separator
- 8 Surge tank
- 9 Thickener mix tanks
- 10 Thickeners
- 11 Surge tank
- 12 NH₃-CO₂ stripping and precipitating tower
- 13 Condenser
- 14 Accumulator and NH₃ absorption tank
- 15 Surge tank
- 16 Heat exchanger
- 17 CO₂ absorption tower
- 18 Pump box
- 19 Regenerated solution storage
- 20 Precipitated solution storage
- 21 Alum solution storage
- 22 Filter press
- P-1 Classifier overflow pump
- P-2 Thickener underflow pump
- P-3 Pulp supply pump
- P-4 Pulp feed to pressure leach pump
- P-5 Pulp transfer pump
- P-6 Thickener underflow pump
- P-7 Pregnant solution feed to Item 12 pump
- P-8 Precipitate transfer pump
- P-9 Feed liquor to carbonation pump
- P-10 Regenerated solution transfer pump
- P-11 Pressure filter feed pump

This drawing is not intended to be a complete detailed piping plan. It shows line sizes and important valves. Additional lines and valves may be added in the field depending on final equipment locations.

FRACTIONAL DIMENSIONS ±			
SCALE	BATTTELLE MEMORIAL INSTITUTE MECHANICAL ENGINEERING DIVISION COLUMBUS, OHIO		
DATE	A.V.K.		
DRAWN BY	CHECKED BY		
SHOP ORDER NO.	PROJECT NO.	DRAWING NO.	
6-2392	6-2392	248	
REV	REVISIONS	NAME	DATE
LET			