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PHOSPHATE ROCK TREATMENT FOR WASTE REDUCTION – PHASE TWO

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PHOSPHATE ROCK TREATMENT FOR WASTE REDUCTION - PHASE TWO

FINAL REPORT

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DISCLAIMER

PERSPECTIVE

Almost all central Florida phosphate rock contains some calcite and dolomite physically combined with the phosphate rock. If it were possible to remove this "free" calcium it would be possible to reduce phosphogypsum production by at least 3%. This type problem is not unknown with other phosphate rocks and one solution to this problem that has been practiced in other parts of the world and has been investigated in this country is to grind the phosphate rock to minus 200 mesh to liberate the dolomite that is combined with the phosphate and use flotation to remove the dolomite from the mixture.

This technique has not been practiced for Florida phosphate rock in large part because of the problems associated with handling minus 200 mesh material. It has always been considered that the rock would be processed at the mine because it would be experienced with flotation, and disposal of the calcite and/or dolomite removed would be simpler. This would obviously require the installation and operation of ball mills at the mine site.

In the study reported on here, Jacobs has taken advantage of the fact that the phosphate rock is now ground at the phosphoric acid plant and while it is not ground to the optimum size of minus 200 mesh, it still should be possible to remove at least enough calcite/dolomite to make a difference. It should also be pointed out that the rock tested under this program is blended to insure that the magnesium content of the rock feed does not exceed a certain level and that by treating rock in this manner it should be possible to make use of some, and perhaps a lot, of the rock that is now discarded due to having too much magnesium.

The testing revealed that it is possible to reduce the calcite/dolomite in the rock and perhaps, even more importantly, that it could be done economically and that in actual practice you would have a return on your investment. The processing proved to be economical because of reduced sulfuric acid use in the phosphoric acid plant and improved costs in DAP manufacture due to the reduced magnesium content of the acid used in DAP.

No attempt was made to assign a value to the reduction in phosphogypsum going to the stack. It is recognized that the elimination of the calcium and magnesium carbonates would reduce defoamer consumption in the phosphoric acid plant but a dollar value has not been assigned to this improvement. The finely ground dolomite/calcite that would be recovered should probably also be assigned a value since it would find a ready market in Florida agriculture, where both neutralizing and magnesium containing materials are in demand. It would not be surprising to find that this material would command a premium for agricultural use due to the fact that the small particle size would equate to rapid availability to the vegetation.

ABSTRACT

The purpose of this second-year test program was to evaluate a previously selected flotation process for carbonate removal. The objectives were for the process to: utilize pond water, remove liberated carbonate materials prior to acidulation, and convert waste rock to reactor feed.

This project consisted of collecting and characterizing two pebble samples, one concentrate sample, and two pond water samples. These samples were subsequently used in laboratory experiments to set up the pilot plant testing. Pilot plant testing was done using low-grade pebble to determine the viability of the carbonate rejection process. Economic analyses were performed based on two different carbonate rejection flowsheets using this process.

This project demonstrated reduction in the $CaO:P_2O_5$ ratio and the minor element ratio (MER). Computations based on mesh by mesh data from the pilot testing demonstrated that low-grade pebble could be combined with concentrate and produce an acceptable product via the carbonate rejection process.

The economic analysis of this process indicated a moderately acceptable payout when low-grade pebble and concentrate were combined and the resulting blend was ground and floated. The life of the hypothetical reserve was extended by 24 percent.

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- Cargill Fertilizer, Inc.
- IMC-Agrico Company
- CF Industries, Inc.
- Custom Chemicals

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EXECUTIVE SUMMARY

As phosphate mining moves to the southern extension of the central Florida phosphate district, the deposits contain a lower ore zone with higher levels of calcium and magnesium carbonates. These impurities increase the cost of producing phosphate fertilizers and increase the amount of phosphogypsum produced.

In 1995, the Florida Institute of Phosphate Research identified phosphogypsum and phosphogypsum pond water as one of the research priorities. Concurrently, Jacobs was performing a study for FIPR to identify means of reducing carbonate contamination (FIPR contract no. 94-01-112R). This program identified the IMC process as the best process among three tested to reduce carbonate contamination prior to phosphoric acid production. This process performs flotation at a pH of about 5.5 using a sulfonated oleic acid collector for carbonate minerals and sodium tripolyphosphate as a phosphate depressant.

Jacobs began the current test program, based on the 1995 study, with the following objectives in mind:

- utilize pond water
- remove liberated carbonates prior to acidulation
- conversion of waste rock to reactor feed

The first phase of the project consisted of sample collection and characterization wherein samples of pebble, concentrate and pond water were collected and analyzed for subsequent use in bench-scale testing.

The laboratory testing was performed as bench-scale batch flotation tests. These tests examined the performance of the IMC carbonate rejection process on treated and untreated phosphate rock. These tests included comparative evaluations of mechanical versus column flotation cells and beneficiation of pebble only versus treatment of pebble-concentrate blend. Locked cycle testing was performed to establish performance data and reagent consumption when recycle water was used in flotation.

A sample of low-grade pebble with an MER $\geq$ 0.12 and $CaO:P_2O_5$ ratio $\approx$ 1.60 was treated in continuous pilot scale tests using the IMC carbonate rejection process. Capital and operating costs were compiled for two flowsheets, one treating waste pebble only and the second one treating combined concentrate, pebble, and waste pebble.

Economic analyses were performed based on the pilot plant results and subsequent capital and operating costs. The standard case, which represented no treatment and no use of waste pebble was compared against the base case, in which combined pebble and concentrate were floated, and the alternate case, in which the waste pebble alone was subjected to flotation.

The project demonstrated that the process would consume 20,000 to 90,000 gallons per day of pond water and that the MER and $CaO:P_2O_5$ ratio can be reduced. The process also showed the hypothetical mine life was increased by 24 and 28 percent, respectively, for the base case and alternate case. Economic analyses yielded a modest return for processing the hypothetical reserve using either the base case or alternate case flowsheets; however, the return on investment for the treatment of combined pebble and concentrate (base case) was greatest. The carbonate rejection process shows technical merit and economic promise.

The pilot plant results confirmed that the flotation of ground reactor feed to remove carbonate impurities is technically feasible. Greater rejection of minor elements and carbonates from the ground rock and/or increased P_2O_5 recovery would significantly improve the economic feasibility of the scheme. Improved flotation efficiency may be possible with phosphate rock ground by devices that preferentially reduce the particle size of the carbonate gangue materials.

INTRODUCTION

BACKGROUND

Phosphate deposits in the southern extension of the Central Florida phosphate district contain Upper and Lower Ore Zones (El-Shall and Bogan 1994). The Upper ore contains mainly grains of francolite (phosphate) and quartz (silica), and clay minerals. The Lower ore zone contains calcium and magnesium carbonate as well as phosphate, silica, and clay. When ore from the Lower zone is mined and beneficiated, the resulting phosphate rock contains increased levels of CaO and MgO. These impurities increase the cost of producing phosphatic fertilizers and increase the production of phosphogypsum per ton of P_2O_5 recovered as wet phosphoric acid.

In 1995, the Florida Institute of Phosphate Research identified phosphogypsum and phosphogypsum pond water as a research priority. The purpose of the research program described in this report was to test a flotation process that could be carried out at a phosphoric acid plant to:

- remove liberated carbonate minerals from the ground rock prior to acidulation. Reducing the $CaO:P_2O_5$ ratio in the reactor feed will reduce phosphogypsum production per ton of recovered P_2O_5.
- utilize pond water as a reagent for pH control and thereby slightly reduce the inventory of low pH pond water at the site.

An additional objective of the research was to investigate the impact of the process on the minor element content ($Fe_2O_3 + Al_2O_3 + MgO$) of the reactor feed. If the reduction in minor elements allows waste rock to be converted to reactor feed, additional severance tax will be generated.

HISTORICAL PERSPECTIVE

Several flotation processes have been developed for removing calcium and magnesium carbonates from phosphate ore; however, not all are well suited for Florida phosphates (El-Shall 1994). The first phase of this project examined three flotation schemes, of which only one gave encouraging results (Gruber 1995).

Characteristics common to most flotation schemes for removing carbonates from phosphate are grinding to liberate the mineral species and flotation in a pulp with acidic pH. The objective of Phase 1 testing was to determine if flotation could be performed with phosphate rock ground at the chemical plant using pond water as a reagent for pH control. Laboratory bench-scale flotation tests performed in Phase I demonstrated that the IMC Anionic process (Snow) had technical and economic potential.

As a consequence of a favorable Phase 1 outcome, a proposal was submitted for a Phase 2 program. Phase 2, comprising laboratory testing, pilot plant testing, and estimation of capital and operating costs was awarded under FIPR Contract No. 96-01-138R.

PROJECT IMPLEMENTATION

The project comprised seven tasks, which were performed sequentially.

Task 1--Sample Collection

Jacobs obtained two samples of low-grade pebble, one sample of low-grade concentrate, and two samples of pond water for characterization and bench-scale testing.

- Pebble ($CaO:P_2O_5 \geq 1.60$, MER ≥ 0.12)
    - beneficiation plant A (Fort Green Mine)
    - beneficiation plant B (Hookers Prairie Mine)

- Concentrate ($CaO:P_2O_5 \geq 1.46$, MER ≥ 0.08)
    - beneficiation plant A or B

- Pond Water
    - acid plant A (South Pierce Plant)
    - acid plant B (Zephyrhills Plant)

Task 2--Sample Characterization

Jacobs performed the following sieve and chemical analyses on the two pebble samples (as received).

Fraction	% Wt.	% P_2O_5	% Acid Insol.	% CaO	% MgO	% I&A
>6.70 mm	X	X	X	X	X	X
6.70/3.35 mm	X	X	X	X	X	X
3.35/1.70 mm	X	X	X	X	X	X
1.70/1.18 mm	X	X	X	X	X	X
<1.18 mm	X	X	X	X	X	X

Jacobs also analyzed the concentrate head sample for the above components. The two pond water samples were analyzed by Jacobs for pH, redox potential, P_2O_5, F, SO_4, Ca, and Mg.

The two pebble samples were ground to pass 10 mesh and the following sieve and chemical analyses were performed on the -10 mesh material.

Fraction	% Wt.	% P_2O_5	% Acid Insol.	% CaO	% MgO	% I&A
>600 microns	X	X	X	X	X	X
600/212 microns	X	X	X	X	X	X
212/74 microns	X	X	X	X	X	X
74/38 microns	X	X	X	X	X	X
38/20 microns	X	X	X	X	X	X
<20 microns	X	X	X	X	X	X

Task 3--Laboratory Testing

Following completion of Task 2, Jacobs performed laboratory batch tests as outlined below:

Series A: Eighteen formal tests to examine the performance of the process developed in the initial study on Fort Green pebble, Hookers Prairie pebble, and a blend of pebble and concentrate. Six tests were conducted at various reagent dosages on each sample.

Series B: Twelve formal tests to examine the impact of pebble pretreatment on the process developed in the initial study. The same three phosphate rock samples tested as above were tested at four different reagent dosages.

Series C: Sixteen formal tests to compare process performance with and without pebble pretreatment on two phosphate rock samples (pebble and pebble-concentrate blend). Laboratory flotation was conducted in a mechanical cell and a column cell. The statistically designed tests allowed the following comparisons:

- The performance of the IMC Anionic Process with and without pebble pretreatment
- Mechanical flotation cell performance vs. column cell performance
- The performance on pebble only vs. the performance on a pebble-concentrate blend.

Concentrates and waste streams from the above 46 formal tests were weighed and analyzed for P_2O_5 and acid insol. Additionally, CaO, MgO, Fe_2O_3, and Al_2O_3 analyses were performed so that comprehensive material balances could be prepared.

Task 4--Locked Cycle Tests

Jacobs performed a total of sixty formal locked cycle tests for anionic flotation with and without pebble pretreatment. These tests established performance data and reagent consumption data when recycle water was used for flotation

Task 5--Pilot Plant Testing

A sample of low-grade pebble meeting the criteria of MER ≥ 0.12 and $CaO:P_2O_5 \geq 1.60$ was collected and prepared. Jacobs performed pilot scale testing on the low-grade pebble sample to confirm the flotation process under continuous operating conditions. The type of flotation cell (mechanical vs. column) and pebble pretreatment were examined.

The pilot plant testing was performed with reject pebble from the South Fort Meade Mine and the phosphogypsum pond water from the Zephyrhills Chemical Complex.

Task 6--Capital and Operating Costs

Following laboratory and pilot plant testing, Jacobs developed two process flowsheets and material balances for the flotation modules, one with and the other without pebble pretreatment. The material balances were based on providing reactor feed for a 1000 ton P_2O_5 per day phosphoric acid plant.

Jacobs estimated the constructed cost of each flowsheet and the operating cost for each flowsheet. The constructed cost for each flowsheet was developed as a factored estimate based on the total costs of priced equipment.

METHODOLOGY

TASK 1

Samples of low-grade pebble from four wet rock storage piles were analyzed to ascertain if they met the target specification for quality. As a consequence of the preliminary chemical analyses, two drums of low-grade pebble were collected, one each from Hookers Prairie and Fort Green. Only one concentrate sample meeting the target specification for quality was found. One drum of concentrate was collected from the Fort Green wet rock pile. The drums were fitted with two bag liners and lids for transport to the Jacobs laboratory.

Each of the above samples was thoroughly blended by Jacobs' laboratory procedure P925-010, as listed below:

Rock Blending and Sampling Procedure

Step 1. Unload the material onto a clean, paved area large enough to accommodate the blending process.

Step 2. Subdivide the material into four main conical piles (A, B, C, D) of approximately equal size.

<u>NOTE</u>: Steps 3 through 8 should be performed separately on each of the four main piles.

Step 3. Form cone-shaped piles by shoveling material from the base of the main pile and placing sequential shovelfuls of material on the apex of the smaller piles. Repeat this process until the main pile is depleted. Take care to load shovels equally, reducing the load as the main pile becomes smaller.

Step 4. Flatten each of the cone-shaped piles into a disc by scraping material from the cone in an outward direction with shovels, starting at the bottom of the cone and moving repeatedly around the cone until a flat disc is formed.

Step 5. Blend each disc by shoveling material from the perimeter back into the center, reforming a small pile from each disc.

Step 6. Recombine the small piles into a single large pile by placing successive shovel loads from each of the small piles onto the apex of the cone forming the large pile.

Step 7. Repeat steps 3, 4, 5 and 6 four times in sequence to give a total of 5 cycles, then repeat step 3 to the end with blended material in small piles.

Step 8. To prepare blended lots, use a shovel or scoop to remove the required material from each of the piles and place in a plastic bag. The remaining material should be placed in a clean, lined drum and sealed until needed

Approximately 150 liters of pond water were collected from the South Pierce Chemical Plant and from the Zephyrhills Chemical Plant. In each case the pond water sample was obtained under the supervision of plant personnel and placed in a plastic lined drum for transport to Jacobs' laboratory.

TASK 2

After blending, samples of the three materials were chemically analyzed using procedure approved by the Association of Florida Phosphate Chemists (AFPC). Samples of the two low-grade pebble products were sieved on a rotap for 10 minutes and the sieve fractions were analyzed using procedures approved by the AFPC.

The pond water samples were chemically analyzed as follows:

pH: hydrogen ion electrode
Redox: specific ion electrode
P_2O_5: AFPC photometric method (page 11-10)
CaO: AFPC EDTA volumetric method (page 9-29)
MgO: AFPC atomic adsorption method (page 11-28)
F: AFPC specific ion; electrode method (page 11-35)
SO_4: AFPC gravimetric method (page 11-39)

TASK 3

Task 3 comprised three series of tests. Series A examined the flotation of ground Fort Green pebble, ground Hookers Prairie pebble, and a blend of Fort Green pebble and concentrate. Series B examined flotation of same three materials after pretreatment to remove clays. Series C was a statistically designed experiment to test two ground materials, with and without pretreatment, using a mechanical laboratory flotation cell and a column flotation cell.

Series A

The three different materials were each ground in a 200 mm diameter rod mill rotating at 75 rpm and containing 18.8 kg of rods ranging from 19 to 38 mm in diameter.

The ground rock was wet screened on 28 mesh and the +28 mesh was added to the mill feed and reground. The -28 mesh was dewatered in a pressure filter, blended, and separated into representative charges of nominally 500 gm (dry basis) for flotation.

The 500 gram charges, stored in sealed plastic ziplock bags, were floated using Jacobs laboratory procedure P925-032, as listed below:

Flotation Bench Testing Procedure

Step 1. Transfer the ground sample[a] from the bench rod mill into a 2-liter stainless steel beaker, add dilution water to adjust to 70% solids by weight.

Step 2. Place the charge under the conditioner[b]. Add the phosphate depressant and pH modifier to adjust the pH[c] to 5.0. Condition for 15 seconds.

Step 3. Add the collector and condition for two minutes. Maintain the pH at 5.5.

Step 4. Transfer the conditioned feed into a 3-litre stainless steel flotation cell. Add dilution water, agitate for 10 minutes while adjusting the pH to 5.5. Turn the air on and float[d] for two minutes. Maintain the cell pH at 5.5. Add water to the flotation cell as needed.

Step 5. Record all pertinent data, including reagent identification, reagent usage, and pH.

Step 6. Dewater the concentrate (sink) and tailings (float). Transfer the products into pans, label and tag product pans for each test and set aside.

Step 7. Dry each sample and record the dry weights. Riffle split out two 50-100 gram samples; reserve one sample as reference and grind the other for analysis[e].

(a) Ground feed charge - 500 grams (dry basis)
(b) Labmaster LIU08 with 4-bladed cruciform propeller - operated at 300 rpm, unless otherwise specified.
(c) Extech Model 607 digital pH motor, or equivalent.
(d) DECO model D-12 laboratory flotation machine; cell rpm of 1000 used unless otherwise specified.
(e) As required.

The flotation reagents used, as well as their dilution and dispenser, are listed below:

Reagent	Dilution	Dispenser
Collector		
Westvaco CCS-502	587 gm/liter	micro-burette
	(active ingredients)	
Phosphate Depressant		
Sodium Tripolyphosphate (STPP)	100 gm/liter	10 ml pipette
pH Modifiers		
Sulfuric Acid	100 gm/liter	10 ml pipette
Pond Water	as received	10 ml pipette

Series B

Three levels of pretreatment were examined for each of the three phosphate samples. The first level of pretreatment was autogenous scrubbing in a tumbling mill at 50 percent solids for five minutes, followed by wet screening at 20 microns. The -20 micron material was rejected. The +20 micron material was ground and floated using the procedures described under Series A. The second level of pretreatment was identical to the first, except that the scrubber feed slurry was adjusted to pH 5.5 with South Pierce pond water. The third level of pretreatment utilized only South Pierce pond water to make up the 50 percent solids scrubber feed.

Series C

A two factor experimental design with replication was used to test flotation cell type and pretreatment type on Fort Green pebble and a blend of Fort Green pebble and concentrate.

Flotation Cell Type.

- mechanical cell: Denver model D12 lab cell
- column cell: Hollingsworth 3 inch lab cell

Treatment Type.

- without: grinding without prior scrubbing and desliming
- with: grinding with prior scrubbing at pH 3.5 followed by desliming at 20 micron

Analysis of variance of the resulting data were performed using Excel 5, Anova: Two-Factor with Replication.

The Hollingsworth column cell utilized a mixed polyglycol frother (F-507) which was metered into the eductor as a two percent solution. The column cell was fed the 500 gm of conditioned feed in a quasi continuous mode.

TASK 4

Fort Green low-grade pebble was subjected to locked cycle flotation tests. Two 10 kg lots of pebble were ground to pass 28 mesh and floated without pretreatment. The first 10 kg lot used South Pierce pond water for pH control in grinding, conditioning, and flotation in a mechanical cell. The second 10 kg lot used Zephyrhills pond water for pH control. Two of the 10 kg lots of Fort Green pebble were pretreated by autogenous scrubbing for five minutes at 50 percent solids and pH 3.5. After scrubbing, the slurry was wet screened at 200 mesh to remove clays. The ≥200 mesh was ground to pass 28 mesh and floated. The third and fourth 10 kg lots were pretreated, ground, and floated using South Pierce pond water and Zephyrhills pond water, respectively, for pH control

The concentrate and tailing from each locked cycle test were dewatered in the pressure filter and the filtrates were used as cell make up for the next test. In this way, the influence of recycle water on flotation can be examined by laboratory tests.

TASK 5

The initial pilot plant configuration consisted of a vari-speed screw feeder, attrition scrubbers, a sand pump, a Derrick desliming screen, a rod mill, diaphragm pump, duplex conditioner, and 200 mm diameter column cell using a CESL sparger. This configuration was abandoned because of surging problems in the attrition scrubber and choking problems in the sand pump.

Although the attrition scrubber and sand pump were eliminated from the flowsheet for the second configuration, this configuration did not work reliably because surges of mill discharge caused the diaphragm pump to choke.

The third pilot plant configuration consisted of the vari speed screw feeder, the rod mill, the duplex conditioner, the diaphragm pump, and the 200 mm column cell. This configuration operated reliably, but did not yield an acceptable performance.

A duplex mechanical cell was substituted for the 200 mm column cell in the fourth pilot plant configuration. Reliability was maintained and performance improved slightly.

The fifth pilot plant configuration duplicated the fourth configuration, but included batch attrition scrubbing of the low-grade pebble prior to continuous testing. Batch scrubbing was performed on 50 kg lots at 50 percent solids for five minutes. Desliming was accomplished on the Derrick screen.

A listing of the continuous process equipment used in the third, fourth, and fifth pilot plant configurations follows.

- <u>Vari Speed Screw Feeder</u>
  model: bootleg special
  screw: 3 inch diameter
  D.C. motor: 0 to 31 rpm, 1/8 hp (full load rpm = 31)
- <u>Derrick Screen</u>
  model: J24-36MS-1
  cloth: DF 370
- <u>Rod Mill</u>
  model: Hazen-Quinn HQ-168-679
  dimensions: 406 mm diameter, 1,220 mm long
  rpm: 43 (70% C.S.)
  rod charge: 279 kg
- <u>Duplex Conditioner</u>
  tank dimensions: 200 mm diameter, 270 mm tall
  impellers: cruciform, 130 mm diameter
  shaft rpm - 603
- <u>Diaphragm Pump</u>
  dimensions: 28.78 mm H, 19.05 mm W, 20.32 mm L
  flow: 13 gpm at 20 SCFM air
- <u>Flotation Cells</u>

<u>mechanical</u>	<u>column</u>
model: Wemco #18 duplex	model: Jacobs design
volume: 0.28 m^3 x 2 cells	dimensions: 200 mm diameter
impeller rpm: 930	and 2.4 m high

The reject pebble sample utilized in the pilot plant testing was obtained from the South Fort Meade mine. The reject pebble included a coarse fraction which was crushed to pass 12.5 mm in the laboratory jaw crusher. Approximately 2,700 kg of coarse pebble were crushed, riffle-split into eight fractions, and stored in eight plastic lined drums. A blend of 20 percent crushed pebble and 80 percent fine reject pebble was prepared as feed to the pilot plant.

For the reliable flowsheet configurations, timed samples were collected at 20 minute intervals for concentrate, tailings, screen undersize, and screw feeder discharge. At the end of a test, the composite samples were weighed wet, then dried and weighed dry to determine rates and percent solids. The dried samples were analyzed for P_2O_5, acid insolubles, and MgO. On the confirmation test, the dried samples were sieved on a rotap and the sieve fractions analyzed.

The duration of the pilot plant program, from test 1 to test 23, was nominally two months, including time for flowsheet changes, preparation/blending of the pebble, chemical analysis, and data evaluation. The rates of blended pebble, water, and reagents for single tests were held constant over a start-up period and subsequent sampling period. A start-up period of 60 to 90 minutes was maintained to assure equilibrium had been reached for the constant rates.

TASK 6

Two flowsheets (flotation modules) for removing carbonates by flotation of ground reactor feed with their respective material balances were prepared. The new equipment items required for each flotation module were sized using process design criteria and the flowrates determined in the material balances for the 1,000 tons per day phosphoric acid plants.

The purchase price of the new equipment was obtained from recent in-house equipment files or by telephone requests for quotations to vendors by Jacobs process and purchasing personnel.

Estimated constructed costs were prepared by Jacobs estimator from proprietary factors applied to the equipment prices to obtain various components of the estimate which were summed to give the total constructed cost of each flotation module.

RESULTS

TASK 1

Based on telephone conversations with personnel from phosphate mines in Polk and Hardee Counties, four candidate sites were selected for sampling and analysis of the two low-grade pebble samples and one low-grade concentrate sample. Analyses of four low-grade pebble samples and the only low-grade concentrate sample are compared to the target quality specifications in Table 1.

Table 1. Chemical Analyses of Candidate Samples.

Specification	% P_2O_5	% CaO	% ME[(1)]	MgO	$CaO:P_2O_5$	MER[(2)]
Pebble					≥ 1.60	≥ 0.12
Concentrate					≥ 1.46	≥ 0.08
Pebble Site						
1	27.19	40.53	4.30	0.74	1.491	0.158
2	23.16	36.93	5.08	1.23	1.595	0.219
3	22.38	37.24	2.32	0.53	1.664	0.104
4	23.54	38.43	4.25	1.68	1.663	0.181
Concentrate Site						
4	30.97	45.79	3.20	0.45	1.479	0.103

(1) % ME = % minor elements = % MgO + % Fe_2O_3 + Al_2O_3

(2) MER = minor element ratio = % ME / % P_2O_5

Based on the above data and the availability of pebble, it was decided to collect nominally 220 kg of low-grade pebble from each of sites 3 (Hookers Prairie) and 4 (Fort Green). Approximately 300 kg of low-grade concentrate were collected from site 4 (Fort Green).

TASK 2

Characterization of Low-Grade Fort Green Pebble

Sieve and chemical analyses, as shown in Table 2, confirm that the target quality specifications for $CaO:P_2O_5$ and minor element ratio (MER) were met by the low-grade Fort Green pebble sample. The data in Table 2 indicate that selective rejection of CaO or MgO by size separation of the as received pebble is not a possibility. For example, sizing the pebble at 6.7 mm (3 mesh) and rejecting the oversize would remove 7.34 and 8.88

percent of the MgO and CaO, respectively; however, 8.99 percent of the P_2O_5 would also be lost.

Table 2. Analyses of "As Received" Low-Grade Fort Green Pebble.

	Analyses				Ratios	
Fraction	% P_2O_5	% Insol.	% CaO	% M.E.	CaO:P_2O_5	MER
+6.7 mm	17.78	16.35	36.33	8.90	2.043	0.501
6.7/3.35 mm	23.96	13.01	41.28	5.34	1.723	0.223
3.35/1.70 mm	26.76	11.69	42.79	2.80	1.599	0.142
1.70/1.18 mm	26.18	16.31	40.68	3.57	1.544	0.136
-1.18 mm	20.80	32.92	32.73	3.19	1.574	0.153
composite	23.77	18.96	38.82	4.31	1.633	0.181

	Distributions				
Fraction	% P_2O_5	% Insol.	% CaO	% MgO	% Weight
+6.7 mm	7.25	8.36	9.08	36.71	9.7
6.7/3.35 mm	14.61	9.95	15.42	22.49	14.5
3.35/1.70 mm	31.52	17.26	30.86	17.89	28.0
1.70/1.18 mm	23.34	18.24	22.22	10.52	21.2
-1.18 mm	23.27	46.18	22.43	12.38	26.6
composite	100.00	100.00	100.00	100.00	100.00

A representative sample of the Fort Green pebble was ground to pass 1.70 mm (10 mesh). Sieve and chemical analyses of the ground pebble are presented in Table 3. The data in Table 3 shows that partial grinding preferentially reduced the MgO particle size relative to the phosphate particle size. For example, if the partially ground Fort Green pebble was deslimed, the predicted upgrading at various desliming cut points is shown in Table 4.

Table 3. Analyses of Partially Ground Low-Grade Fort Green Pebble.

	Analyses				Ratios	
Fraction	% P_2O_5	% Insol.	% CaO	% M.E.	$CaO:P_2O_5$	MER
+600 microns	24.94	16.78	41.13	3.84	1.649	0.154
600/212 microns	22.59	24.79	36.03	3.72	1.595	0.165
212/74 microns	23.06	22.73	37.98	3.98	1.647	0.173
74/38 microns	24.21	11.98	42.49	5.90	1.755	0.244
38/20 microns	19.45	7.00	40.68	9.80	2.092	0.504
-20 microns	22.38	7.62	43.84	9.74	1.959	0.435
composite	23.67	19.30	39.24	4.32	1.658	0.183

	Distributions				
Fraction	% P_2O_5	% Insol.	% CaO	% MgO	% Weight
+600 microns	45.95	37.90	45.70	33.65	43.6
600/212 microns	32.64	43.93	31.40	26.18	34.2
212/74 microns	10.62	12.84	10.55	8.62	10.2
74/38 microns	4.19	2.54	4.44	7.44	4.1
38/20 microns	1.40	0.62	1.76	7.65	1.7
-20 microns	5.20	2.17	6.14	16.45	5.5
composite	100.00	100.00	100.00	100.00	100.0

Table 4. Fort Green Pebble Quality After Partial Grinding and Desliming.

Desliming				% Recovery	
Cutpoint	% P_2O_5	$CaO:P_2O_5$	MER	P_2O_5	Weight
38 microns	23.82	1.635	0.164	93.4	92.8
20 microns	23.74	1.641	0.169	94.8	94.5
0 microns	23.67	1.658	0.183	100.0	100.0

Desliming of partially ground low-grade Fort Green pebble would improve quality; however, a minimum of five percent P_2O_5 losses are indicated.

Characterization of Low-Grade Hookers Prairie Pebble

The sieve and chemical analyses shown in Table 5 indicate that the low-grade Hookers Prairie Pebble sample did not meet target specification for either $CaO:P_2O_5$ or MER. A representative sample of the pebble was ground to pass 1.70 mm (10 mesh). Sieve and chemical analyses of the ground pebble are given in Table 6.

Table 5. Analyses of "As Received" Low-Grade Hookers Prairie Pebble.

	Analyses				Ratios	
Fraction	% P_2O_5	% Insol.	% CaO	% M.E.	$CaO:P_2O_5$	MER
+6.7 mm	29.67	7.53	45.94	2.53	1.548	0.085
6.7/3.35 mm	29.19	7.47	45.94	3.21	1.574	0.110
3.35/1.70 mm	29.03	8.25	45. 49	3.03	1.567	0.104
1.70/1.18 mm	27.51	14.35	42.94	2.70	1.561	0.098
-1.18 mm	16.47	48.75	25.97	1.89	1.577	0.115
composite	23.76	25.54	37.24	2.50	1.568	0.105

	Distributions				
Fraction	% P_2O_5	% Insol.	% CaO	% MgO	% Weight
+6.7 mm	8.99	2.12	8.88	7.34	7.2
6.7/3.35 mm	14.13	3.36	14.19	15.50	11.5
3.35/1.70 mm	27.86	7.36	27.85	32.71	22.8
1.70/1.18 mm	21.08	10.23	20.98	20.76	18.2
-1.18 mm	27.94	76.92	28.10	23.68	40.3
composite	100.00	100.00	100.00	100.00	100.00

Table 6. Analyses of Partially Ground Low-Grade Hookers Prairie Pebble.

	Analyses				Ratios	
Fraction	% P_2O_5	% Insol.	% CaO	% M.E.	$CaO:P_2O_5$	MER
+600 microns	25.89	17.96	41.28	2.72	1.594	0.105
600/212 microns	21.28	32.90	32.73	2.17	1.538	0.102
212/74 microns	24.58	23.33	37.53	2.46	1.527	0.100
74/38 microns	27.04	14.13	42.49	2.95	1.571	0.109
38/20 microns	27.62	10.11	43.69	3.48	1.582	0.126
-20 microns	26.93	8.06	43.84	5.57	1.628	0.207
composite	24.12	23.59	37.85	2.58	1.569	0.107

	Distributions				
Fraction	% P_2O_5	% Insol.	% CaO	% MgO	% Weight
+600 microns	49.27	34.94	50.06	48.42	45.9
600/212 microns	32.99	52.15	32.34	29.89	37.4
212/74 microns	9.88	9.59	9.62	9.15	9.7
74/38 microns	3.70	1.98	3.70	3.75	3.3
38/20 microns	1.03	0.39	1.04	1.50	0.9
-20 microns	3.13	0.96	3.24	7.30	2.8
composite	100.00	100.00	100.00	100.00	100.0

Characterization of Water Samples

Chemical analyses of the two pond water samples and laboratory (City of Lakeland) water are shown in Table 7.

Table 7. Analyses of Pond Water and Tap Water.

			ppm				
Pond Water	pH	Redox	P_2O_5	CaO	MgO	F	SO_4
South Pierce	1.35	218	16,800	3,400	600	3,400	7,900
Zephyrhills	1.55	230	14,800	2,000	400	2,900	9,000
Tap Water							
10/22/97	--	--	1.1	77	15	0.8	--
11/4/97	--	--	1.1	83	16	0.8	--
11/18/97	--	--	1.1	70	15	0.9	--

TASK 3

Series A

The "as received" low-grade pebble samples from Fort Green and Hookers Prairie, and the blend of pebble and concentrate from Fort Green were ground to pass 600 microns (28 mesh) and floated using the IMC anionic process. Analyses of the ground low-grade pebble samples are given in Table 8. The -20 micron fraction of both ground pebble samples has a relatively high concentration of minor elements and an elevated $CaO:P_2O_5$ ratio; however, 8.5 to 14.5 percent of the P_2O_5 would be lost if this fraction were removed by desliming.

The six flotation tests performed on Fort Green Pebble are summarized in Table 9. The best concentrate quality was obtained in test 3, where the $CaO:P_2O_5$ was reduced from 1.58 to 1.49 and the MER was reduced from 0.174 to 0.135, at 90.7 percent P_2O_5 recovery. The consumptions of pH modifier (H_2SO_4) and phosphate depressant (STPP) were relatively constant for the six tests and averaged 4.03 and 0.76 kg/ton feed, respectively.

The six carbonate flotation tests results from Hookers Prairie pebble are tabulated in Table 10. Very little improvement in percent P_2O_5 resulted from carbonate flotation of this material; however, about one third of the MgO was rejected at all dosages of collector. The consumption of pH modifier (H_2SO_4) was low for this sample (about 2.45 kg/t) because of the low carbonate content of the rock. The STPP consumption was constant at 0.75 kg/ton feed.

Six carbonate flotation tests were also performed on a blend of low-grade pebble and concentrate from Fort Green. The target grade of the blend was 28 percent P_2O_5 . Flotation test results are presented in Table 11. The best concentrate quality was obtained in test 3, where the $CaO:P_2O_5$ ratio was reduced from 1.518 to 1.494 and the MER from 0.133 to 0.116, at 96.9 percent P_2O_5 recovery. The collector dosage for the blend was about one half that of pebble. The STPP consumption was not varied from that of the pebble only. The consumption of pH modifier was reduced to 2.2 kg/ton because of lower carbonate content.

Table 8. Analyses of Ground Low-Grade Pebble Samples.

Sieve	Analysis (%)						Ratio	Distribution (%)				
Microns	P_2O_5	A.I.	Fe_2O_3	Al_2O_3	MgO	CaO	CaO/P_2O_5	Weight	P2O5	A.I.	M.E.	CaO
Fort Green Pebble												
>425	23.98	21.52	1.74	0.73	0.74	38.25	1.595	7.3	7.4	8.0	5.6	7.3
425/300	24.03	21.60	1.56	0.84	0.84	38.40	1.598	16.8	17.0	18.5	13.0	16.8
300/212	23.03	24.98	1.43	0.88	0.87	36.45	1.583	18.1	17.6	23.1	13.8	17.2
212/150	22.40	26.56	1.44	0.93	0.82	35.69	1.593	14.0	13.2	18.9	10.7	13.0
150/105	23.30	23.78	1.45	1.03	0.87	35.99	1.545	8.8	8.6	10.6	7.0	8.2
105/74	24.61	19.65	1.47	1.17	0.90	38.70	1.573	6.6	6.8	6.6	5.6	6.6
74/38	25.29	15.16	1.54	1.23	1.60	40.51	1.602	10.4	11.1	8.0	10.8	11.0
38/20	21.98	9.08	1.47	1.25	4.90	41.57	1.891	4.2	3.9	1.9	7.6	4.5
<20	24.56	6.07	1.97	2.25	3.55	42.02	1.711	14.0	14.5	4.3	25.9	15.3
Calculated Head	23.71	19.61	1.57	1.14	1.47	38.32	1.616	100.0	100.0	100.0	100.0	100.0
Analyzed Head	23.77	19.50	1.65	1.13	1.38	38.25	1.609					
Hookers Prairie Pebble												
>425	22.66	28.30	1.38	0.57	0.52	35.39	1.562	15.8	15.7	16.3	9.8	15.6
425/300	21.72	31.72	1.24	0.52	0.51	34.34	1.581	24.1	23.0	27.8	9.0	23.1
300/212	21.24	33.01	1.18	0.54	0.51	33.13	1.560	17.7	16.4	21.2	8.9	16.3
212/150	22.24	30.41	1.16	0.58	0.53	34.64	1.558	11.9	11.6	13.1	9.0	11.5
150/105	23.09	27.88	1.15	0.60	0.56	35.84	1.552	7.1	7.2	7.2	9.2	7.1
105/74	24.14	24.23	1.14	0.61	0.58	37.80	1.566	5.5	5.8	4.8	9.3	5.8
74/38	25.14	20.46	1.27	0.64	0.64	39.16	1.558	8.1	8.9	6.0	10.2	8.8
38/20	26.56	14.54	1.87	0.71	0.90	41.57	1.565	2.6	3.1	1.4	13.9	3.1
<20	26.82	8.70	2.40	1.19	1.60	42.77	1.595	7.2	8.5	2.3	20.7	8.6
Calculated Head	22.85	27.55	1.33	0.61	0.62	35.81	1.567	100.0	100.0	100.0	100.0	100.0
Analyzed Head	22.82	27.77	1.33	0.62	0.60	35.54	1.557					

Table 9. Carbonate Flotation of Ground "As Received" Fort Green Pebble.

Test		Analysis (%)						Ratio	% Distribution		Collector
Number	Product	P_2O_5	A.I.	Fe_2O_3	Al_2O_3	MgO	CaO	CaO/P_2O_5	Weight	P_2O_5	Kg/t feed
1	Conc.	25.00	21.00	1.64	1.21	0.78	37.72	1.509	90.4	93.8	
	Tails	15.78	5.46	1.34	1.38	8.30	42.00	2.662	9.6	6.2	
	Calc. head	24.12	19.52	1.61	1.23	1.50	38.13	1.581	100.0	100.0	0.43
2	Conc.	24.84	21.86	1.62	1.10	0.70	37.72	1.519	88.3	91.4	
	Tails	17.69	5.13	1.39	1.43	7.10	42.73	2.415	11.7	8.6	
	Calc. head	24.00	19.90	1.59	1.14	1.45	38.31	1.596	100.0	100.0	0.58
3	Conc.	25.16	22.15	1.60	1.11	0.68	37.57	1.493	87.5	90.7	
	Tails	18.06	4.60	1.40	1.46	7.20	43.47	2.407	12.5	9.3	
	Calc. head	24.27	19.96	1.58	1.15	1.49	38.31	1.578	100.0	100.0	0.64
4	Conc.	25.11	21.40	1.62	1.07	0.67	37.42	1.490	87.0	89.9	
	Tails	18.91	4.95	1.42	1.51	6.80	44.20	2.337	13.0	10.1	
	Calc. head	24.30	19.26	1.59	1.13	1.47	38.30	1.576	100.0	100.0	0.75
5	Conc.	24.95	22.57	1.62	1.07	0.67	37.42	1.500	84.7	86.9	
	Tails	20.71	4.60	1.50	1.57	6.00	43.47	2.099	15.3	13.1	
	Calc. head	24.30	19.82	1.60	1.15	1.49	38.35	1.578	100.0	100.0	0.86
6	Conc.	24.82	21.20	1.59	1.20	0.76	37.90	1.527	92.2	95.4	
	Tails	14.03	4.66	1.31	1.21	9.60	38.08	2.714	7.8	4.6	
	Calc. head	23.98	19.91	1.57	1.20	1.45	37.91	1.581	100.0	100.0	0.32

Table 10. Carbonate Flotation of Ground "As Received" Hookers Prairie Pebble.

Test		Analysis (%)						Ratio	% Distribution		Collector
Number	Product	P_2O_5	A.I.	Fe_2O_3	Al_2O_3	MgO	CaO	CaO/P_2O_5	Weight	P_2O_5	Kg/t feed
1	Conc.	22.93	29.50	1.40	0.64	0.46	34.92	1.523	94.2	93.8	
	Tails	24.47	7.60	1.73	0.81	3.50	43.32	1.770	5.8	6.2	
	Calc. head	23.02	28.23	1.42	0.65	0.64	35.41	1.538	100.0	100.0	0.43
2	Conc.	22.67	29.96	1.29	0.61	0.44	34.48	1.521	92.2	91.0	
	Tails	26.38	6.08	1.63	0.80	2.80	44.49	1.687	7.8	9.0	
	Calc. head	22.96	28.09	1.32	0.62	0.62	35.26	1.536	100.0	100.0	0.58
3	Conc.	22.83	30.48	1.29	0.60	0.44	34.18	1.497	91.3	89.9	
	Tails	26.85	6.15	1.64	0.81	2.60	44.94	1.674	8.7	10.1	
	Calc. head	23.18	28.35	1.32	0.62	0.63	35.12	1.515	100.0	100.0	0.64
4	Conc.	22.62	30.47	1.24	0.58	0.44	34.33	1.518	91.2	89.8	
	Tails	26.75	6.70	1.65	0.80	2.50	45.38	1.696	8.8	10.2	
	Calc. head	22.98	28.38	1.28	0.60	0.62	35.30	1.536	100.0	100.0	0.75
5	Conc.	22.88	30.38	1.28	0.59	0.45	34.33	1.500	90.7	89.1	
	Tails	27.17	5.84	1.62	0.81	2.50	45.09	1.660	9.3	10.9	
	Calc. head	23.28	28.09	1.31	0.61	0.64	35.34	1.518	100.0	100.0	0.85
6	Conc.	23.17	28.84	1.32	0.62	0.46	35.36	1.526	94.2	94.0	
	Tails	24.34	7.30	1.73	0.83	3.60	42.10	1.730	5.8	6.0	
	Calc. head	23.24	27.60	1.34	0.63	0.64	35.75	1.538	100.0	100.0	0.32

Table 11. Carbonate Flotation of Fort Green Pebble-Concentrate Blend.

Test		Analysis (%)						Ratio	Percent Distribution		Collector
Number	Product	P_2O_5	A.I.	Fe_2O_3	Al_2O_3	MgO	CaO	CaO/P_2O_5	Weight	P_2O_5	Kg/t feed
1	Conc.	28.33	11.60	1.50	1.33	0.72	42.82	1.511	97.6	98.9	
	Tails	12.96	4.40	1.26	1.19	10.90	36.21	2.794	2.4	1.1	
	Calc. head	27.96	11.42	1.49	1.33	0.97	42.66	1.526	100.0	100.0	0.11
2	Conc.	28.59	11.58	1.49	1.35	0.59	42.97	1.503	96.1	98.2	
	Tails	12.70	7.36	1.28	1.23	9.80	35.55	2.799	3.9	1.8	
	Calc. head	27.97	11.41	1.48	1.35	0.95	42.68	1.526	100.0	100.0	0.21
3	Conc.	28.86	11.65	1.48	1.31	0.55	43.12	1.494	94.5	96.9	
	Tails	16.05	7.90	1.39	1.65	7.60	36.35	2.265	5.5	3.1	
	Calc. head	28.16	11.44	1.48	1.33	0.94	42.75	1.518	100.0	100.0	0.32
4	Conc.	28.54	11.68	1.48	1.25	0.55	42.82	1.500	93.2	95.4	
	Tails	18.70	8.10	1.48	2.12	6.45	37.11	1.984	6.8	4.6	
	Calc. head	27.87	11.44	1.48	1.31	0.95	42.43	1.522	100.0	100.0	0.42
5	Conc.	28.60	11.84	1.49	1.24	0.55	43.12	1.508	92.7	94.8	
	Tails	19.93	7.95	1.46	2.30	5.70	37.59	1.886	7.3	5.2	
	Calc. head	27.97	11.56	1.49	1.32	0.92	42.72	1.527	100.0	100.0	0.52
6	Conc.	28.70	11.62	1.47	1.28	0.54	42.97	1.497	95.0	97.3	
	Tails	14.88	7.80	1.35	1.28	8.40	36.58	2.458	5.0	2.7	
	Calc. head	28.01	11.43	1.46	1.28	0.93	42.65	1.523	100.0	100.0	0.32

Series B

Three levels of pretreatment were tested for each phosphate sample. The first level of pretreatment was scrubbing in a tumbling mill at 50 percent solids for five minutes, followed by decantation and wet screening at 20 microns (630 mesh). The second level of pretreatment was identical to the first, except that the slurry pH was adjusted to 5.5 with South Pierce pond water. The third level of pretreatment utilized South Pierce pond water instead of tap water for scrubbing.

This testing was performed to establish the materials balance for pretreatment and to prepare pretreated rock for subsequent grinding and flotation testing. Conceptually, pretreatment would remove fines, low in P_2O_5 content, that are detrimental to conditioning and flotation.

The materials balance for each test compares the input of solids plus liquids to the outputs. For calculation purposes, all liquid output is allocated to the decant water. The +20 and -20 micron fractions of rock were dried and weighed. For the pond water scrub tests, the rock fractions were rinsed with tap water prior to drying, and the -20 micron material was corrected for the precipitated sludge from the decant water. The precipitate amounted to 7 grams/liter of decant and analyzed 1.1% P_2O_5, 2.0% SiO_2, 37% CaO, 0.0% MgO, 4.37% Fe_2O_3, 0.0% Al_2O_3, 26.4% SO_3, and 11.0% F.

The mass balances for the first level of pretreatment on the three samples are given in Table 12. The closure errors for ambient pH scrubbing and desliming were low at two percent or less. P_2O_5 losses due to scrubbing and desliming at 20 microns were less than three percent.

The mass balances for the second level of pretreatment on the three samples are presented in Table 13. The closure errors remain low at two percent or less and the P_2O_5 losses from desliming at 20 microns also remain below three percent.

The mass balances for the third level of pretreatment are presented in Table 14. Some dissolution of rock and some precipitation of calcium compounds occurred with this treatment. Closure errors were as high as nine percent for MgO. Analyses of the composite liquid output and input for the third level of pretreatment, as shown in Table 15, confirm that P_2O_5, CaO, and MgO are leached to a minor extent from the rock by pond water scrubbing. The resulting pH of the output liquid remains below 1.9 and therefore is unsuitable for discharge. Recycle of this material back to the pond water system would add both CaO and MgO to the system.

The +20 micron fraction from the third level of pretreatment for each phosphate rock sample was ground and floated. Pond water was used for pH control in conditioning and flotation. The purpose of the flotation tests was to measure the flotation performance at different levels of collector usage.

Results from four flotation tests performed on Fort Green pebble after pond water scrubbing, desliming, and grinding are presented in Table 16. Pretreatment appears to have reduced the consumption of collector. Difficulty in blending the low-grade pebble due to the more variable quality coarse particles was evidenced by quality differences between the flotation feeds from grinding vs. pretreatment and grinding. These differences in quality influenced the flotation results.

Results from flotation tests performed on Hookers Prairie pebble, and the Fort Green blend of pebble and concentrate, after pond water scrubbing, desliming, and grinding are shown in Tables 17 and 18, respectively. Reduced consumption of collector on material that had been pretreated was more evident for the blend of concentrate and pebble from Fort Green than for Hookers Prairie low-grade pebble.

Aside from reducing the quantity of collector required, the third level of pretreatment did not appear to improve performance over that of ground phosphate rock.

Table 12. Mass Balances for Ambient pH Scrubbing and Desliming.

	grams				
Low-Grade Fort Green Pebble	Weight	P_2O_5	Insol	CaO	MgO
+20 micron solids	1,954	463	374	762	31
-20 micron solids	46	10	5	17	2
decant water	2,000	0	0	0	0
total output	4,000	474	379	779	33
total input	4,000	475	379	776	32
% closure error	0	0	0	(0)	(1)
Low-Grade Hookers Prairie Pebble					
+20 micron solids	1,978	449	553	701	12
-20 micron solids	10	2	1	3	0
decant water	2,013	0	0	0	0
total output	4,000	452	554	705	12
total input	4,000	456	555	711	12
% closure error	0	1	0	1	1
Low-Grade Fort Green Blend					
+20 micron solids	1,979	554	229	840	19
-20 micron solids	17	4	2	6	1
decant water	2,004	0	0	0	0
total output	4,000	558	230	846	19
total input	4,000	560	229	853	19
% closure error	0	0	(1)	1	(2)

Note: All numbers rounded to nearest gram or whole percentage point.

Table 13. Mass Balances for pH 5.5 Scrubbing and Desliming.

	grams				
Low-Grade Fort Green Pebble	Weight	P_2O_5	Insol	CaO	MgO
+20 micron solids	1,954	463	374	763	31
-20 micron solids	44	10	4	16	2
decant water	2,000	0	0	0	0
total output	4,000	474	378	779	33
total input	4,000	475	379	777	32
% closure error	0	0	0	(0)	(1)
Low-Grade Hookers Prairie Pebble					
+20 micron solids	1,982	450	555	703	12
-20 micron solids	8	2	1	3	0
decant water	2,010	0	--	0	0
total output	4,000	452	555	706	12
total input	4,000	456	555	711	12
% closure error	0	1	(0)	1	1
Low-Grade Fort Green Blend					
+20 micron solids	1,981	555	229	841	19
-20 micron solids	18	4	2	6	1
decant water	2,001	0	--	0	0
total output	4,000	559	231	847	19
total input	4,000	560	229	853	19
% closure error	(0)	0	(1)	1	(2)

Note: All numbers rounded to nearest gram or whole percentage point.

Table 14. Mass Balances for Pond Water Scrubbing and Desliming.

	grams				
Low-Grade Fort Green Pebble	Weight	P_2O_5	Insol	CaO	MgO
+20 micron solids	1,938	455	388	733	33
-20 micron solids	58	10	5	21	1
decant water	2,004	32	--	10	3
total output	4,000	497	393	763	37
total input	4,000	505	379	782	33
% closure error	0	2	(3)	3	(9)
Low-Grade Hookers Prairie Pebble					
+20 micron solids	1,969	447	556	703	11
-20 micron solids	22	2	1	8	0
decant water	2,009	38	--	13	2
total output	4,000	487	558	724	13
total input	4,000	488	555	717	13
% closure error	0	0	(0)	(1)	4
Low-Grade Fort Green Blend					
+20 micron solids	1,963	545	241	834	16
-20 micron solids	28	3	2	10	0
decant water	2,009	36	--	12	2
total output	4,000	584	242	856	19
total input	4,000	590	229	859	20
% closure error	0	1	(6)	0	6

Note: All numbers rounded to nearest gram or whole percentage point.

Table 15. Third Level Pretreatment Liquid Analyses.

ppm P_2O_5	Outputs	Inputs	Increase
Fort Green Pebble	15,900	14,817	1,083
Hookers Prairie Pebble	18,700	15,746	2,954
Fort Green Blend	17,700	15,110	2,590
average			2,209
ppm CaO			
Fort Green Pebble	4,810	2,970	1,840
Hookers Prairie Pebble	6,300	3,152	3,148
Fort Green Blend	6,000	3,028	2,972
average			2,653
ppm MgO			
Fort Green Pebble	1,250	492	758
Hookers Prairie Pebble	810	522	288
Fort Green Blend	910	502	408
average			485
pH Level			
Fort Green Pebble	1.83	1.35	0.48
Hookers Prairie Pebble	1.65	1.35	0.30
Fort Green Blend	1.75	1.35	0.40
average			0.39

Table 16. Carbonate Flotation of Fort Green Pebble After Level 3 Pretreatment.

Test		Analysis (%)						Ratio	% Distribution		Collector
Number	Product	P_2O_5	A.I.	Fe_2O_3	Al_2O_3	MgO	CaO	CaO/P_2O_5	Weight	P_2O_5	Kg/T Feed
1	Conc.	23.98	20.82	1.63	1.11	1.10	37.51	1.564	95.6	98.3	
	Tails	8.79	3.40	1.35	0.91	16.00	33.18	3.775	4.4	1.7	
	Calc. head	23.31	20.05	1.62	1.10	1.76	37.32	1.601	100.0	100.0	0.11
2	Conc.	24.03	21.62	1.60	1.04	0.86	37.51	1.561	92.3	95.8	
	Tails	12.59	4.00	1.44	1.47	12.60	34.72	2.758	7.7	4.2	
	Calc. head	23.15	20.26	1.59	1.07	1.77	37.29	1.611	100.0	100.0	0.21
3	Conc.	24.34	21.87	1.61	1.10	0.80	37.51	1.541	90.7	94.0	
	Tails	15.29	3.72	1.47	1.56	10.60	36.10	2.361	9.3	6.0	
	Calc. head	23.50	20.19	1.60	1.14	1.71	37.38	1.591	100.0	100.0	0.32
4	Conc.	23.87	22.16	1.60	1.00	0.80	37.07	1.553	89.2	92.4	
	Tails	16.23	3.75	1.50	1.62	9.80	37.46	2.308	10.8	7.6	
	Calc. head	23.05	20.18	1.59	1.07	1.77	37.11	1.610	100.0	100.0	0.42

Table 17. Carbonate Flotation Tests on Hookers Prairie Pebble After Level 3 Pretreatment.

Test		Analysis (%)						Ratio	% Distribution		Collector
Number	Product	P_2O_5	A.I.	Fe_2O_3	Al_2O_3	MgO	CaO	CaO/P_2O_5	Weight	P_2O_5	Kg/T Feed
1	Conc.	22.68	28.15	1.45	0.66	0.47	35.14	1.549	98.4	98.6	
	Tails	19.30	9.90	2.15	0.82	6.65	37.52	1.944	1.6	1.4	
	Calc. head	22.63	27.78	1.46	0.66	0.57	35.08	1.550	100.0	100.0	0.11
2	Conc.	22.62	29.15	1.35	0.63	0.45	34.99	1.547	96.8	96.9	
	Tails	21.79	10.43	2.08	0.88	4.30	39.07	1.793	3.2	3.1	
	Calc. head	22.59	28.54	1.37	0.64	0.57	35.12	1.555	100.0	100.0	0.21
3	Conc.	22.52	29.50	1.30	0.60	0.44	34.84	1.547	95.4	95.3	
	Tails	23.35	11.62	1.98	0.87	3.30	38.90	1.666	4.6	4.7	
	Calc. head	22.56	28.69	1.33	0.61	0.57	35.02	1.553	100.0	100.0	0.32
4	Conc.	22.78	29.68	1.30	0.57	0.43	34.84	1.529	94.9	94.5	
	Tails	24.50	10.22	1.90	0.88	2.95	40.33	1.646	5.1	5.5	
	Calc. head	22.87	28.69	1.33	0.59	0.56	35.12	1.536	100.0	100.0	0.42
	Analy. head	22.73	28.25	1.33	0.64	0.55	35.73	1.572			

Table 18. Carbonate Flotation on Fort Green Blend After Level 3 Pretreatment.

Test		Analysis (%)						Ratio	% Distribution		Collector
Number	Product	P_2O_5	A.I.	Fe_2O_3	Al_2O_3	MgO	CaO	CaO/P_2O_5	Weight	P_2O_5	Kg/T Feed
1	Conc.	28.35	12.47	1.46	1.34	0.58	43.00	1.517	97.8	99.1	
	Tails	11.70	6.40	1.55	1.16	12.70	33.32	2.848	2.2	0.9	
	Calc. head	27.99	12.29	1.46	1.33	0.84	42.64	1.523	100.0	100.0	0.11
2	Conc.	28.20	12.32	1.46	1.33	0.54	42.85	1.520	96.8	98.3	
	Tails	14.62	9.85	1.67	1.68	9.80	33.55	2.295	3.2	1.7	
	Calc. head	27.77	12.24	1.47	1.34	0.84	42.55	1.533	100.0	100.0	0.21
3	Conc.	28.03	12.16	1.56	1.22	0.53	42.70	1.523	96.3	97.9	
	Tails	15.55	10.90	1.66	2.42	9.00	32.29	2.077	3.7	2.1	
	Calc. head	27.57	12.11	1.56	1.26	0.84	42.31	1.535	100.0	100.0	0.32
4	Conc.	28.20	12.46	1.45	1.21	0.51	43.00	1.525	95.7	97.4	
	Tails	16.64	10.77	1.58	2.59	8.00	32.62	1.960	4.3	2.6	
	Calc. head	27.71	12.39	1.46	1.27	0.83	42.56	1.536	100.0	100.0	0.42

Series C

The two-factor experimental design with replication was selected. Duplicate tests of two values of each factor (variable) were performed, requiring eight tests per phosphate rock sample.

2 factors x 2 values x 2 tests = 8 tests per design

One design was performed with Fort Green Pebble and a second with a blend of Fort Green pebble and concentrate.

Flotation Cell Type.

- mechanical cell: Denver model D12 lab cell
- column cell: Hollingsworth 3 inch lab cell

Treatment Type.

- without: grinding without prior scrubbing and desliming
- with: scrubbing at pH 3.5 followed by desliming at 20 micron followed by grinding of >20 micron material

Analysis of variance of the resulting data were performed using Excel 5, Anova: Two-Factor with Replication.

The data from the eight flotation tests of Fort Green pebble are given in Table 19. Cell type and treatment type did not significantly influence the concentrate % MgO, $CaO:P_2O_5$, or % P_2O_5 flotation recovery, however, both variables influenced reagent consumption. The column cell which operated continuously with pressurized water required almost three times as much pond water for pH control during flotation as the batch Denver cell. The pretreatment of Fort Green pebble reduced collector consumption by about 40 percent without influencing flotation performance.

Data from eight flotation tests using a blend of Fort Green pebble and concentrate are presented in Table 20. Statistical analyses of the data show that cell type and treatment type did not significantly influence concentrate % MgO, $CaO:P_2O_5$, or % P_2O_5 flotation recovery. Flotation cell type and mode of operation influenced water usage and thereby influenced the amount of pond water required for pH control in flotation. Collector usage for flotation of rock with and without pretreatment was constant.

Table 19. Comparison of Pretreatment and Cell Types for Flotation of Fort Green Pebble.

Test		Analysis (%)						Ratio	% Distribution		Collector
Pretreatment	Product	P_2O_5	A.I.	Fe_2O_3	Al_2O_3	MgO	CaO	CaO/P_2O_5	Weight	P_2O_5	Kg/T Feed
Denver Flotation Cell											
Without	Conc.	24.43	22.45	1.57	1.05	0.70	37.66	1.542	87.9	90.4	0.47
	Tails	18.74	5.58	1.45	1.86	7.20	38.33	2.045	12.1	9.6	
	Conc.	24.44	21.60	1.58	1.10	0.76	37.43	1.532	89.8	92.8	0.47
	Tails	16.50	5.83	1.43	1.77	8.30	37.07	2.247	10.2	7.2	
With	Conc.	24.27	21.58	1.57	1.07	0.73	38.70	1.595	90.1	91.3	0.27
	Tails	15.08	5.60	1.33	1.54	9.60	37.22	2.468	9.9	8.7	
	Conc.	24.60	21.17	1.52	1.09	0.74	37.72	1.533	92.3	92.8	0.27
	Tails	14.30	4.43	1.24	1.37	11.80	35.11	2.455	7.7	7.2	
Column Flotation Cell											
Without	Conc.	23.58	22.55	1.68	1.05	0.72	37.07	1.572	89.0	89.8	0.47
	Tails	18.87	4.71	1.45	1.73	7.20	39.23	2.079	11.0	10.2	
	Conc.	24.22	21.90	1.54	1.09	0.80	37.87	1.564	90.8	92.2	0.47
	Tails	17.20	3.93	1.33	1.72	8.30	38.26	2.224	9.2	7.8	
With	Conc.	24.11	21.35	1.59	1.05	0.73	37.81	1.568	90.0	91.2	0.27
	Tails	15.37	5.33	1.28	1.53	9.20	37.38	2.432	10.0	8.8	
	Conc.	24.70	21.22	1.56	1.06	0.82	38.81	1.571	91.5	93.9	0.27
	Tails	11.76	5.45	1.31	1.49	10.20	36.01	3.062	8.5	6.1	

Table 20. Comparison of Pretreatment and Cell Types for Flotation of Fort Green Blend.

Test		Analysis (%)						Ratio	% Distribution		Collector
Pretreatment	Product	P_2O_5	A.I.	Fe_2O_3	Al_2O_3	MgO	CaO	CaO/P_2O_5	Weight	P_2O_5	Kg/T Feed
Denver Flotation Cell											
Without	Conc.	28.71	11.77	1.43	1.29	0.56	42.70	1.487	95.8	89.8	0.27
	Tails	13.60	11.73	1.36	2.13	9.30	33.02	2.428	4.2	10.2	
	Conc.	28.88	11.66	1.40	1.28	0.56	42.44	1.470	95.9	91.7	0.27
	Tails	13.50	12.21	1.32	2.32	9.70	31.32	2.320	4.1	8.3	
With	Conc.	29.03	12.50	1.44	1.06	0.56	42.55	1.466	94.6	90.0	0.27
	Tails	16.50	11.00	1.28	2.17	7.90	34.93	2.117	5.4	10.0	
	Conc.	28.50	12.06	1.36	1.25	0.58	42.14	1.479	95.1	91.9	0.27
	Tails	15.20	10.66	1.30	1.94	8.70	33.68	2.216	4.9	8.1	
Column Flotation Cell											
Without	Conc.	28.44	11.85	1.40	1.33	0.56	42.63	1.499	94.0	89.8	0.27
	Tails	18.10	11.93	1.42	2.33	6.60	35.01	1.934	6.0	10.2	
	Conc.	28.61	11.50	1.38	1.27	0.58	42.44	1.483	94.1	91.7	0.27
	Tails	18.37	11.90	1.57	2.03	6.50	34.70	1.889	5.9	8.3	
With	Conc.	28.50	12.16	1.48	1.02	0.57	42.85	1.504	94.7	89.9	0.27
	Tails	16.38	12.26	1.25	2.45	7.60	33.51	2.046	5.3	10.1	
	Conc.	28.66	11.98	1.34	1.20	0.58	42.58	1.486	94.5	91.9	0.27
	Tails	16.30	12.42	1.29	2.25	7.50	33.30	2.043	5.5	8.1	

The results show no performance difference for mechanical or column laboratory flotation cells. The higher water use and consequential higher use of pH modifier by the column cell resulted because of the mode of operation. The column cell was operated in quasi continuous mode while the Denver cell was operated in batch mode.

Results of the analysis of variance for the two samples are summarized below.

	Fort Green Pebble	Fort Green Blend
Concentrate % MgO		
cell type	F = 1.077	F = 1.000
pretreatment type	F = 0.088	F = 1.000
Concentrate $CaO:P_2O_5$		
cell type	F = 1.554	F = 4.721
pretreatment type	F = 0.996	F = 0.015
% P_2O_5 Recovery		
cell type	F = 0.001	F = 0.001
pretreatment type	F = 0.674	F = 0.033

Note: To be significant at the 95% confidence level, the F value must exceed 7.709.

TASK 4

Feed Preparation

Twenty kilograms of Fort Green pebble were ground to pass 600 microns (28 mesh). Ten kilograms were ground using South Pierce pond water for pH control and ten kilograms were ground using Zephyrhills pond water for pH control. The pH of dilution water to achieve 65 percent solids was 3.5, which resulted in a pH of 5.5 for the mill feed. Chemical analyses of the ground rock are presented in Table 21.

Table 21. Grinding Fort Green Pebble Without Pretreatment.

		Analyses, ppm				
Decant Water (Grinding)	Grams	P_2O_5	A.I.	MgO	CaO	F
South Pierce Pond Water	35,369	2	0	22	119	3
Zephyrhills Pond Water	34,541	2	0	29	130	3
Average	34,955	2	0	26	125	3

		Analyses, %				
Ground Flotation Feed	Grams	P_2O_5	A.I.	MgO	CaO	CaO/P_2O_5
South Pierce Pond Water	10,009	23.29	19.87	1.50	38.10	1.636
Zephyrhills Pond Water	10,030	23.14	19.66	1.59	38.54	1.666
Average	10,020	23.21	19.77	1.55	38.32	1.651

% Recovery to -74 Micron	0	0	0	0	0	
% Dissolution Losses	0	0	0	0	0	
% Recovery to Flotation Feed	100	100	100	100	100	

Another twenty kilograms of Fort Green pebble were scrubbed at 50 percent solids for five minutes using dilution water of pH 3.5. After scrubbing, the slurry was deslimed at 74 microns (200 mesh). One half of the samples were ground using South Pierce pond water as the pH modifier and Zephyrhills pond water was used as the pH modifier for the other half. After desliming the +74 micron material was ground to pass 600 microns. Analyses of the materials are given in Table 22.

The data show that about four percent of the P_2O_5 is lost and 16 percent of the MgO is rejected due to the pretreatment. Desliming at 74 microns, although much more practical than desliming at 20 microns, increases P_2O_5 losses from about two to four percent and increases the MgO rejection from about four to 16 percent.

Locked Cycle Flotation Tests

Each locked cycle test was started with a collector dosage of 0.63 pounds per ton of flotation feed and a STP dosage of 1.5 pounds per ton. With locked cycle testing, the water recovered from the concentrate and tailings of test "N" are used as make-up water for test "N+1". In this way, laboratory tests can simulate the use of recycle water.

The 14 flotation tests comprising the locked cycle testing of Fort Green pebble without pretreatment and using South Pierce pond water as a pH modifier are presented in Table 23. Results of the corresponding tests using Zephyrhills pond water as a pH modifier are given in Table 24. The use of recycle water had only a slight effect on flotation performance of untreated Fort Green pebble as evidenced by the following comparison.

	Flotation % Recovery w/o Pretreatment				
	Weight	P_2O_5	A.I.	MgO	CaO
First 7 cycles (avg.)	89.7	92.1	95.5	49.4	90.6
Last 7 cycles (avg.)	89.2	92.2	94.8	49.3	90.0

The 28 flotation tests performed on pretreated Fort Green pebble are displayed in Tables 25 and 26 using South Pierce pond water and Zephyrhills pond water, respectively, as pH modifier. The use of recycle water for floating the pretreated Fort Green pebble had only a slight effect on flotation performance. The following comparison shows a similar trend to that with untreated pebble.

	Flotation % Recovery with Pretreatment				
	Weight	P_2O_5	A.I.	MgO	CaO
First 7 cycles (avg.)	91.6	93.1	99.0	47.0	91.2
Last 7 cycles (avg.)	91.2	93.8	98.2	47.5	90.5

Table 22. Grinding Fort Green Pebble With Pretreatment.

		Analyses %				
-74 Micron Slimes	Grams	P_2O_5	A.I.	MgO	CaO	CaO/P_2O_5
South Pierce Pond Water	249	22.57	11.00	4.30	38.49	1.705
Zephyrhills Pond Water	262	23.16	10.23	4.20	38.79	1.675
Average	256	22.87	10.62	4.25	38.64	1.690

		Analyses ppm				
Decant Water (Desliming)	Grams	P_2O_5	A.I.	MgO	CaO	F
South Pierce Pond Water	38,467	4	0	25	110	7
Zephyrhills Pond Water	38,121	7	0	25	100	6
Average	38,294	6	0	25	105	6

		Analyses ppm				
Decant Water (Grinding)	Grams	P_2O_5	A.I.	MgO	CaO	F
South Pierce Pond Water	34,030	2	0	25	100	4
Zephyrhills Pond Water	33,909	9	0	24	120	4
Average	33,970	6	0	25	110	4

		Analyses %				
Ground Flotation Feed	Grams	P_2O_5	A.I.	MgO	CaO	CaO/P_2O_5
South Pierce Pond Water	9,573	23.08	20.58	1.38	37.94	1.644
Zephyrhills Pond Water	9,643	23.62	20.19	1.33	38.09	1.613
Average	9,608	23.35	20.38	1.35	38.02	1.629

% Recovery to -74 Micron	3	3	1	7	3	
% Dissolution Losses	2	1	0	9	2	
% Recovery to Flotation Feed	96	96	99	84	95	

Table 23. Locked Cycle Tests on Fort Green Pebble, South Pierce Pond Water for pH Control.

Test		Analysis (%)				Ratio	Percent Distribution				
Cycle	Product	P_2O_5	A.I.	MgO	CaO	CaO/P_2O_5	Weight	P_2O_5	A.I.	MgO	CaO
1	Concentrate	23.90	21.58	0.81	37.60	1.573	89.53	92.37	95.98	48.68	89.67
2	Concentrate	24.31	21.12	0.81	37.74	1.552	88.62	91.46	95.34	48.49	88.73
3	Concentrate	24.10	21.22	0.82	37.45	1.554	88.94	91.72	95.52	48.51	89.04
4	Concentrate	24.16	21.33	0.81	38.19	1.581	89.42	92.28	95.80	48.74	89.68
5	Concentrate	24.21	21.27	0.82	38.19	1.577	89.16	92.10	95.66	49.08	89.42
6	Concentrate	23.79	21.34	0.84	38.34	1.612	89.61	92.28	95.74	50.50	89.88
7	Concentrate	24.26	21.32	0.84	38.34	1.580	89.36	92.24	95.66	50.20	89.62
8	Concentrate	24.00	21.30	0.83	38.34	1.598	89.18	92.04	95.61	49.07	89.40
9	Concentrate	23.95	21.32	0.84	38.19	1.595	89.11	91.91	95.64	49.53	89.36
10	Concentrate	23.90	21.42	0.83	38.19	1.598	88.28	91.04	95.04	48.63	88.50
11	Concentrate	23.90	21.32	0.85	38.49	1.610	88.63	91.40	95.24	49.36	88.93
12	Concentrate	23.90	21.23	0.84	38.34	1.604	88.88	91.63	95.44	49.33	89.05
13	Concentrate	23.95	21.32	0.84	38.49	1.607	88.86	91.63	95.53	48.56	89.15
14	Concentrate	23.95	21.53	0.85	38.94	1.626	88.48	91.13	95.09	49.36	88.83

Table 24. Locked Cycle Tests on Fort Green Pebble, Zephyrhills Pond Water for pH Control.

Test		Analysis (%)				Ratio	Percent Distribution				
Cycle	Product	P_2O_5	A.I.	MgO	CaO	CaO/P_2O_5	Weight	P_2O_5	A.I.	MgO	CaO
1	Concentrate	23.75	21.20	0.80	38.49	1.621	90.04	93.14	96.52	45.39	90.38
2	Concentrate	23.85	20.80	0.80	38.64	1.620	90.73	93.85	96.74	46.51	91.09
3	Concentrate	23.90	20.82	0.80	38.79	1.623	90.13	93.23	96.29	45.64	90.53
4	Concentrate	23.85	20.78	0.82	38.49	1.614	90.67	93.68	96.51	47.23	91.01
5	Concentrate	23.80	21.27	0.84	38.49	1.617	90.05	93.08	90.35	46.91	90.42
6	Concentrate	23.85	21.16	0.85	38.64	1.620	89.95	93.00	96.27	46.95	90.28
7	Concentrate	24.49	21.32	0.85	39.09	1.596	89.90	94.10	96.17	47.69	90.27
8	Concentrate	23.80	21.03	0.84	38.49	1.617	89.16	92.05	95.67	46.98	89.52
9	Concentrate	23.85	20.70	0.84	38.49	1.614	89.32	92.05	95.66	44.96	89.54
10	Concentrate	23.64	20.64	0.83	38.64	1.635	89.49	92.31	95.81	46.89	89.88
11	Concentrate	24.17	21.05	0.84	38.64	1.599	90.20	93.14	96.23	47.62	90.63
12	Concentrate	23.85	20.90	0.83	38.79	1.626	89.98	92.88	96.12	47.03	90.33
13	Concentrate	24.00	20.45	0.83	38.94	1.623	89.66	92.46	95.71	47.35	90.02
14	Concentrate	24.06	20.68	0.83	39.09	1.625	90.15	92.89	96.11	48.10	90.59

Table 25. Locked Cycle Tests on Deslimed Fort Green Pebble, South Pierce Pond Water for pH Control.

Test		Analysis (%)				Ratio	Percent Distribution				
Cycle	Product	P_2O_5	A.I.	MgO	CaO	CaO/P_2O_5	Weight	P_2O_5	A.I.	MgO	CaO
1	Concentrate	23.77	21.60	0.85	37.78	1.589	92.82	95.10	97.47	56.98	93.07
2	Concentrate	23.66	21.40	0.83	37.92	1.603	92.25	94.53	97.20	55.27	92.31
3	Concentrate	23.71	21.45	0.83	38.07	1.606	91.99	94.17	96.99	55.31	92.04
4	Concentrate	23.82	21.85	0.82	38.07	1.598	91.88	94.17	96.97	54.66	92.02
5	Concentrate	23.61	21.95	0.84	37.85	1.603	92.02	94.13	96.91	56.04	92.05
6	Concentrate	23.82	22.00	0.85	37.92	1.592	92.19	94.33	96.86	57.23	92.28
7	Concentrate	23.45	21.76	0.83	37.78	1.611	91.21	93.29	96.37	54.82	91.23
8	Concentrate	23.66	21.73	0.85	38.07	1.609	92.14	94.23	96.79	57.06	92.24
9	Concentrate	23.50	21.81	0.83	38.07	1.620	91.75	93.87	96.66	55.18	91.82
10	Concentrate	23.61	21.50	0.84	38.07	1.612	91.76	93.90	96.56	56.52	91.87
11	Concentrate	23.50	21.48	0.85	37.92	1.614	91.56	93.61	96.54	55.48	91.61
12	Concentrate	23.50	21.82	0.82	38.07	1.620	91.74	93.88	96.63	55.16	91.86
13	Concentrate	23.50	21.51	0.83	38.07	1.620	91.41	93.49	96.39	54.74	91.47
14	Concentrate	23.45	21.59	0.85	38.07	1.623	91.17	93.10	96.19	55.97	91.27

Table 26. Locked Cycle Tests on Deslimed Fort Green Pebble, Zephyrhills Pond Water for pH Control.

Test		Analysis (%)				Ratio	Percent Distribution				
Cycle	Product	P_2O_5	A.I.	MgO	CaO	CaO/P_2O_5	Weight	P_2O_5	A.I.	MgO	CaO
1	Concentrate	24.20	21.72	0.70	38.12	1.575	91.35	94.04	97.04	48.66	91.40
2	Concentrate	24.15	21.40	0.69	38.19	1.581	91.14	93.76	96.81	47.63	91.36
3	Concentrate	24.31	21.68	0.69	38.04	1.565	91.30	93.94	96.76	48.47	91.33
4	Concentrate	24.15	21.67	0.69	38.19	1.581	91.08	93.56	96.61	48.11	91.15
5	Concentrate	24.31	21.26	0.72	38.19	1.571	91.15	93.64	96.53	49.72	91.25
6	Concentrate	24.15	21.77	0.72	38.04	1.575	90.71	93.14	96.31	49.07	90.80
7	Concentrate	24.10	21.70	0.74	38.04	1.578	90.74	93.12	96.29	49.82	90.84
8	Concentrate	24.25	21.15	0.72	38.04	1.569	90.85	93.31	96.33	49.48	90.95
9	Concentrate	24.36	21.50	0.74	38.19	1.568	90.58	93.05	96.23	49.72	90.73
10	Concentrate	24.36	20.35	0.74	38.19	1.568	90.64	93.12	96.08	49.88	90.81
11	Concentrate	24.25	21.35	0.75	38.19	1.575	90.61	92.92	96.23	50.12	90.69
12	Concentrate	24.36	21.20	0.75	38.19	1.568	91.20	93.54	96.43	51.90	91.30
13	Concentrate	24.31	21.46	0.76	38.19	1.571	90.40	92.78	96.09	50.54	90.45
14	Concentrate	24.36	21.73	0.75	38.04	1.562	90.67	93.02	96.26	51.01	90.73

If the pretreatment desliming losses are incorporated, the overall recovery of concentrate from pebble is two percent lower than without pretreatment. The recovery and product quality with and without pretreatment are given in Table 27.

Table 27. Performance Comparison, With and Without Pretreatment.

% Recovery	Weight	P_2O_5	A.I.	MgO	CaO	$CaO:P_2O_5$
Desliming (avg.)	95.9	96.4	98.9	83.9	95.1	n/a
Flotation (avg.)	91.4	93.5	98.6	47.3	90.8	n/a
Pretreatment Overall	87.7	90.1	97.5	36.7	86.4	n/a
Without Pretreatment	89.5	92.1	95.7	49.4	90.3	n/a
Concentrate Grade						
Pretreatment	--	23.94	21.55	0.78	38.06	1.590
Without Pretreatment	--	23.97	21.12	0.83	38.45	1.604

TASK 5

Waste Pebble Sample

The target quality specification for the blend of crushed coarse reject pebble and fine reject pebble was MER ≥ 0.12 and $CaO:P_2O_5 \geq 1.6$. Analyses of the resultant blend are presented in Table 28. As shown, the MER exceeded the specification and the $CaO:P_2O_5$ ratio was slightly less than the specification.

Table 28. Analyses of Low-Grade Pebble for Pilot Plant Testing.

	Blend	Target
% P_2O_5	26.71	----
% Insol	12.98	----
% CaO	42.25	----
% MgO	1.30	----
% Feral	2.25	----
MER	0.133	≥ 0.120
$CaO:P_2O_5$	1.582	≥ 1.600

Pilot Plant Configurations

The pilot plant flowsheet evolved as a consequence of solving material handling problems related to coarse particles and low flow rates and also because of modifications to improve flotation performance. All told, the pilot plant program examined five equipment arrangements in 23 tests.

Process configuration 1 attempted continuous attrition scrubbing and desliming of the rod mill feed. This configuration was abandoned after test 3. Coarser particles (>6 mm) gradually accumulated in the scrubbers and periodically surged to the sand pump, causing the pump to choke. In process configuration 2, the troublesome scrubbers and pump were eliminated and the pebble was fed directly to the desliming screen upstream of the rod mill. With this configuration the choke point occurred in the diaphragm pump which could not tolerate surges in the rod mill discharge. Process configuration 2 was abandoned after tests 7. Process configurations 1 and 2 are presented as block flow diagrams in Figures 1 and 2, respectively.

Process configuration 3 was similar to the previous configuration, except the duplex conditioner was relocated to receive the rod mill discharge and reagentized feed was pumped to the column cell. This configuration provided for mechanically reliable material handling; however, flotation performance was inferior to laboratory flotation results. A series of laboratory tests were performed on pilot plant ground feed to examine the influence of conditioning (reagentization) parameters on flotation performance. These tests indicated that the difference in agitation intensity and retention time between pilot and laboratory conditioning did not have a major impact on flotation performance. It was therefore concluded that a mechanical flotation cell should be substituted for the column cell. The use of the mechanical cell (process configuration 4) commenced with test 15 and ended with test 18. Process configurations 3 and 4 are presented as block flow diagrams in Figures 3 and 4, respectively.

Process configuration 5 reverted to the original plan of attrition scrubbing and desliming the pebble prior to rod milling. The scrubbing was performed on a batch basis to avoid the material handling problems encountered in configuration 1. The scrubbed pebble was processed by the same equipment as process configuration 4. Tests 19 through 23 were performed using process configuration 5.

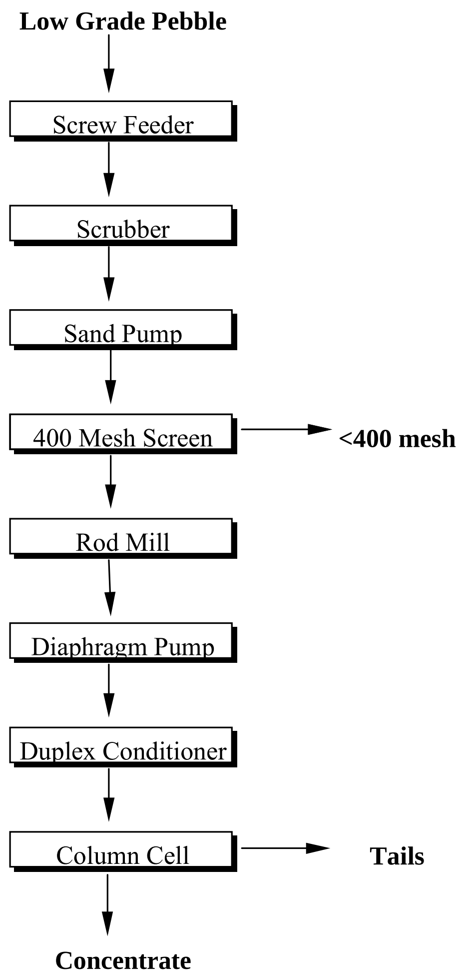


Figure 1. Process Configuration 1.

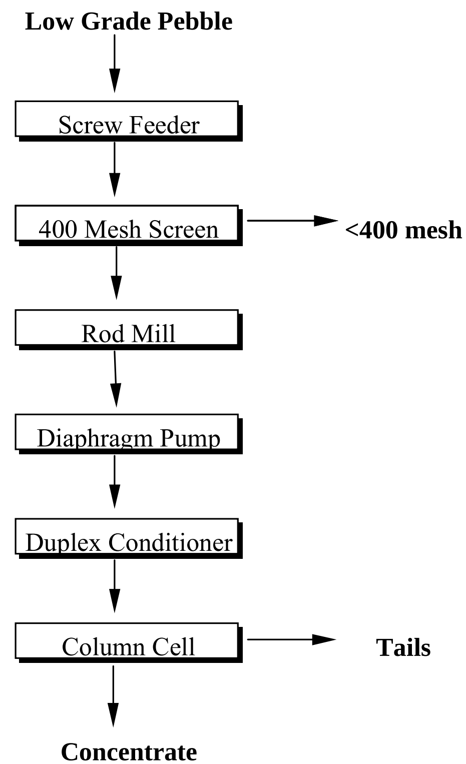


Figure 2. Process Configuration 2.

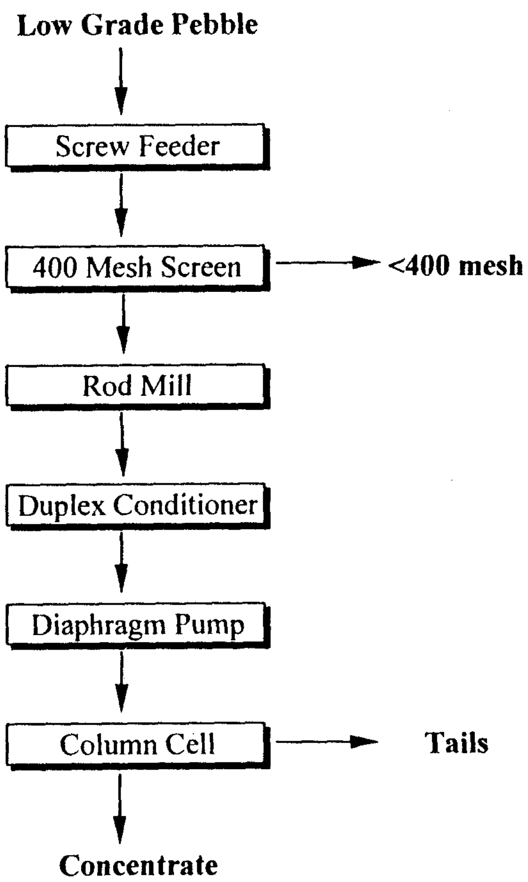


Figure 3. Process Configuration 3.

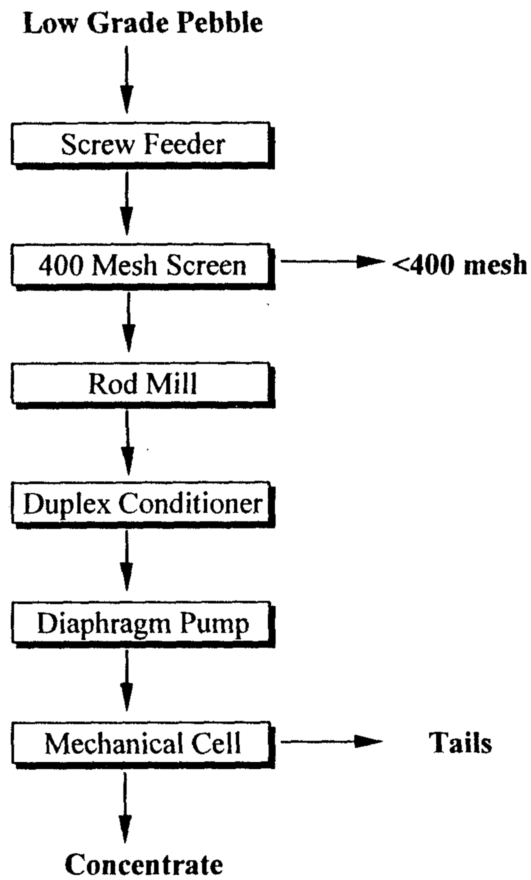


Figure 4. Process Configuration 4.

Pilot Plant Data

The results of the 23 pilot plant tests are summarized in Table 29, and individual report sheets for each of the 21 completed tests are presented in Appendix A. These sheets show materials balance details for each of the completed tests. From Table 29, the gradual improvement in concentrate quality and flotation recovery is evident. The demonstration run (test 23) gave the best overall performance. The results from test 23, which was performed with process configuration 5, are summarized in Figure 5.

The low-grade pebble sample contained some material finer than 38 microns (400 mesh). Desliming this material at 400 mesh would remove minor amounts of P_2O_5 and MgO in addition to the free clay. After crushing the coarse pebble component to pass 12.5 mm, the blend contained about 10.2 percent of <400 mesh, which included about nine percent of the P_2O_5, 25 percent of the Al_2O_3, and 36 percent of the MgO. Crushing the material to an acceptable top size for the pilot plant equipment increased the amount of <400 mesh material, and consequently increased P_2O_5 losses during desliming. From Figure 5 it can be determined that the <400 mesh screen underflow contains 8.7 percent of the P_2O_5 values in the low-grade pebble.

Table 29. Summarized Pilot Plant Results.

		Concentrate		% P_2O_5	Collector	Defoamer[4]
P. C.[1]	Test	% P_2O_5	% MgO	Recovery[2]	Kg/Ton Feed [3]	Kg/Ton Feed [3]
1	1	26.7	0.82	80.4	1.15	0
1	2	aborted				
1	3	aborted				
2	4	26.4	0.89	82.7	1.29	0
2	5	26.7	0.95	88.7	0.81	0
2	6	26.6	0.83	82.9	1.03	0
2	7	26.7	0.81	75.6	1.29	0
3	8	26.6	1.01	84.2	0.96	0
3	9	26.7	0.82	84.6	0.95	0
3	10	29.1	0.85	92.2	0.95	0
3	11	26.9	1.02	94.5	1.88	0
3	12	27.2	0.85	90.6	1.92	0
3	13	27.0	0.87	91.5	2.48	0
3	14	27.0	0.86	91.7	0.89	0
4	15	27.1	0.84	92.7	0.60	0
4	16	27.0	0.83	92.5	0.75	0
4	17	27.0	0.79	88.1	0.98	0
4	18	27.3	0.80	94.1	1.01	3.52
5	19	27.0	0.79	96.3	0.88	3.07
5	20	27.2	0.78	96.7	0.57	1.69
5	21	27.3	0.74	96.0	0.72	2.31
5	22	27.1	0.76	91.9	0.74	2.96
5	23	27.6	0.74	95.1	0.71	3.53

(1) P.C. = Process configuration
(2) Recovery across flotation only
(3) Based on pebble weight before desliming
(4) Diesel oil was the only defoamer tested

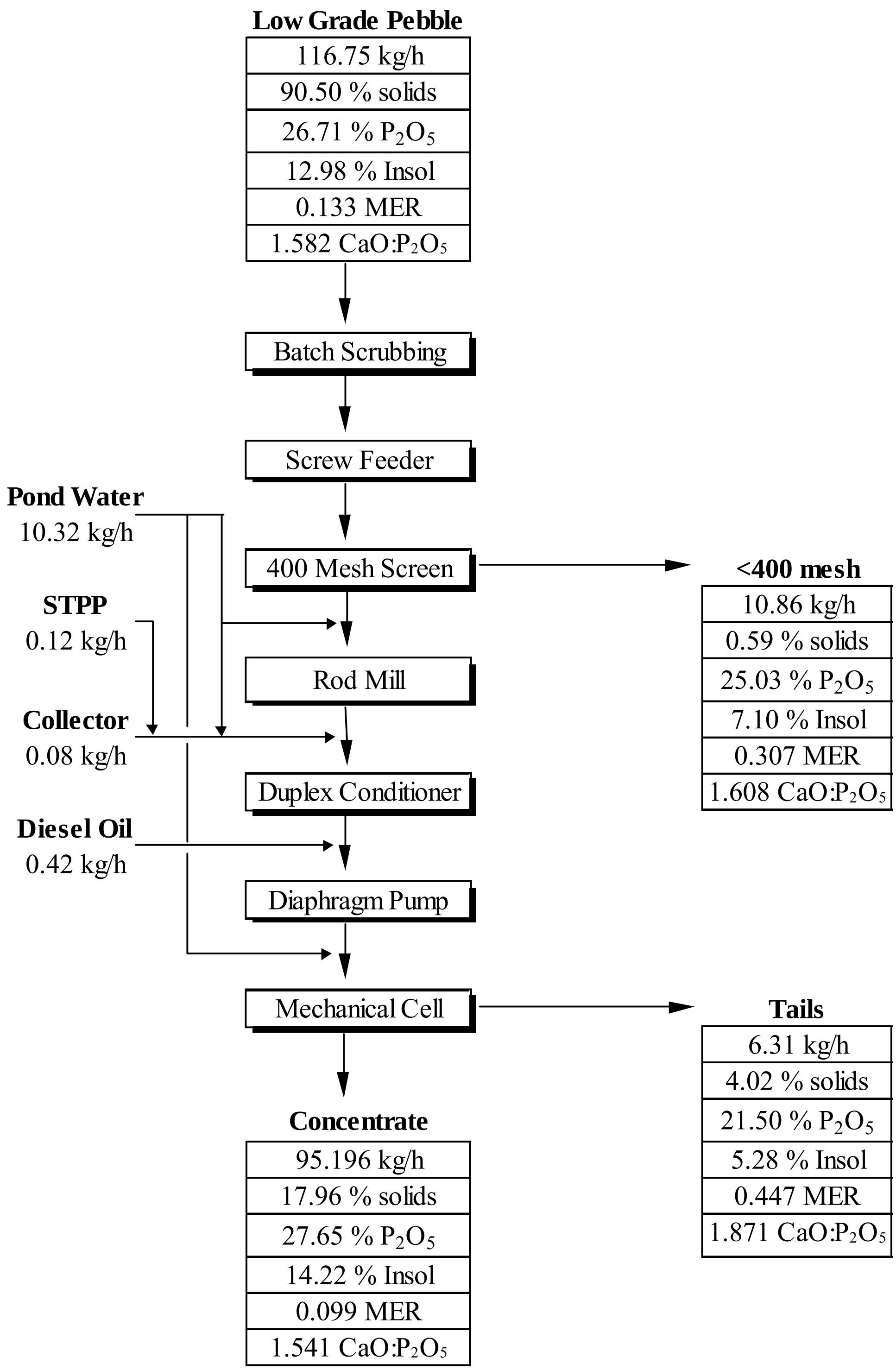


Figure 5. Process Configuration 5.

Excessive foam from the sulfonated tall oil collector was not a significant problem in bench-scale flotation; however, in pilot scale flotation the froth characteristics impaired flotation performance. Tests 17 and 18 were performed on the same day, using identical quantities of STPP and collector, and diesel oil was used as a defoamer in test 18. The test results are compared in Table 30. Table 30 also lists the results of pilot plant flotation of pebble ground after scrubbing and desliming at 400 mesh.

Table 30. Influence of Diesel Oil (Defoamer).

	Unscrubbed		Scrubbed
	w/o d.o.(1)	w.d.o.(2)	w.d.o.(3)
STPP (kg/t conc.)	1.48	1.36	1.26
Collector (kg/t conc.)	1.31	1.21	0.88
Diesel Oil (kg/t conc.)	0.00	4.20	4.41
Low-Grade Pebble (kg/h)	140.7	136.2	116.0
Mill Discharge pH	6.0	6.0	6.1
Conditioner Discharge pH	5.5	5.5	5.5
Flotation Cell pH	5.6	5.5	5.5
Concentrate Quality			
% P_2O_5	27.0	27.3	27.7
% Insol.	13.8	13.4	14.2
% MgO	0.79	0.80	0.74
Concentrate from Pebble			
% Weight Recovery	84.9	90.7	84.7
% P_2O_5 Recovery	86.4	92.3	86.6

(1) test 17, without diesel oil (defoamer)
(2) test 18, with diesel oil (defoamer)
(3) test 23, with diesel oil (defoamer)

The use of diesel oil visibly eliminated excessive frothing and consequently reduced the mechanical carry over of phosphate. Differences in STPP and collector consumption (kg/t conc.) resulted from the difference in concentrate yield. No defoamers other than diesel oil were examined.

Scrubbing and desliming prior to grinding removed clay material and about nine percent of the P_2O_5 content from the flotation feed. Flotation of this feed required lower consumption of STPP and collector and gave superior flotation performance. However, P_2O_5 recovery was reduced due to desliming losses.

Inverse flotation processes in which gangue (either silicate or carbonate) is removed by the froth typically float only particles finer than 212 microns, leaving phosphate and coarse gangue particles to report to the cell underflow. The froth and cell underflow from test 23 were sieved and the fractions analyzed to determine flotation performance by particle size. Test results, as shown in Table 31, confirm that the flotation tailings are essentially finer than 105 microns. The composite analyses agree closely with sample head analyses, confirming that the sampling procedures were reliable.

The calculated recoveries of P_2O_5, acid insoluble, and MgO to the concentrate for the various size fractions are illustrated in Figure 6. This graph shows that P_2O_5 recovery was very high for particles coarser than 105 microns, and that the recovery of MgO was very low for particles smaller than 105 microns. Effective rejection of MgO by flotation was achieved only for particles smaller than 150 microns. It is evident from Figure 6 that the size distributions of P_2O_5 and MgO will influence flotation performance. The fractions smaller than 105 microns were not analyzed for the pilot plant samples; however, bench testing data indicate that P_2O_5 recoveries decreased from 97 percent in the 105/74 micron fraction to 66 percent in the <38 micron fraction. The corresponding MgO recoveries decreased from 63 to 17 percent.

The distributions of materials in the ground flotation feed from test 23 are shown in Figure 7, and indicate that differences in mineral hardness result in preferential grinding. It has been shown (Sotillo 1997) that High Pressure Grinding Rolls (HPGR) enhance preferential grinding of phosphate pebble and increase the amount of MgO in the <105 micron fraction. If HPGR could grind pebble to a size consist acceptable for phosphoric acid production, a marked improvement in flotation performance should result.

The data presented in Figures 6 and 7 were obtained using ground pebble that had been deslimed at 400 mesh prior to grinding. From Figure 6 we see that flotation selectively rejects MgO from the <105 micron fraction. The sole purpose of desliming is to remove free clays that consume reagents and promote frothing.

Two samples of concentrate from test 23 were thickened in 2000 ml graduate cylinders, without flocculant. The averaged settling rate curve for the concentrate is shown on Figure 8. The settling rate was relatively rapid for the first hour. The initial and final concentrations of solids were 17.7 and 60.0 percent respectively. However, the settled solids had two visible components. The bottom component contained about 90 percent of the weight at 73.18 percent solids. The top component contained about 10 percent of the weight at 21.78 percent solids. In a raked thickener with continuous feed, the top component of less dense material would never form and the settled material would be expected to have a composite density of 68 percent solids or more.

Table 31. Test 23 Analyses by Size Fraction.

Concentrate	% Weight	% P_2O_5	% Insol.	% MgO
>425 microns	6.41	28.29	11.26	0.99
425/300 microns	12.33	27.62	13.89	0.86
300/212 microns	17.96	26.55	16.92	0.83
212/150 microns	14.59	26.33	17.55	0.72
150/105 microns	10.24	26.22	18.05	0.63
<105 microns	38.48	28.45	10.81	0.66
composite	100.00	27.46	14.04	0.74
head		27.65	14.22	0.74

Tailings	% Weight	% P_2O_5	% Insol.	% MgO
>425 microns	0.00			
425/300 microns	0.00			
300/212 microns	0.84	18.61	16.87	5.20
212/150 microns	1.14	13.45	15.74	10.20
150/105 microns	2.04	12.14	14.91	12.30
<105 microns	95.98	21.71	4.61	7.05
composite	100.00	21.39	5.05	7.18
head		21.50	5.28	7.20

Feed	% Weight	% P_2O_5	% Insol.	% MgO
>425 microns	6.01	28.29	11.26	0.99
425/300 microns	11.56	27.62	13.89	0.86
300/212 microns	16.89	26.53	16.92	0.84
212/150 microns	13.75	26.26	17.54	0.77
150/105 microns	9.73	26.04	18.01	0.78
<105 microns	42.06	27.49	9.93	1.57
composite	100.00	27.08	13.48	1.14
head		27.27	13.66	1.14

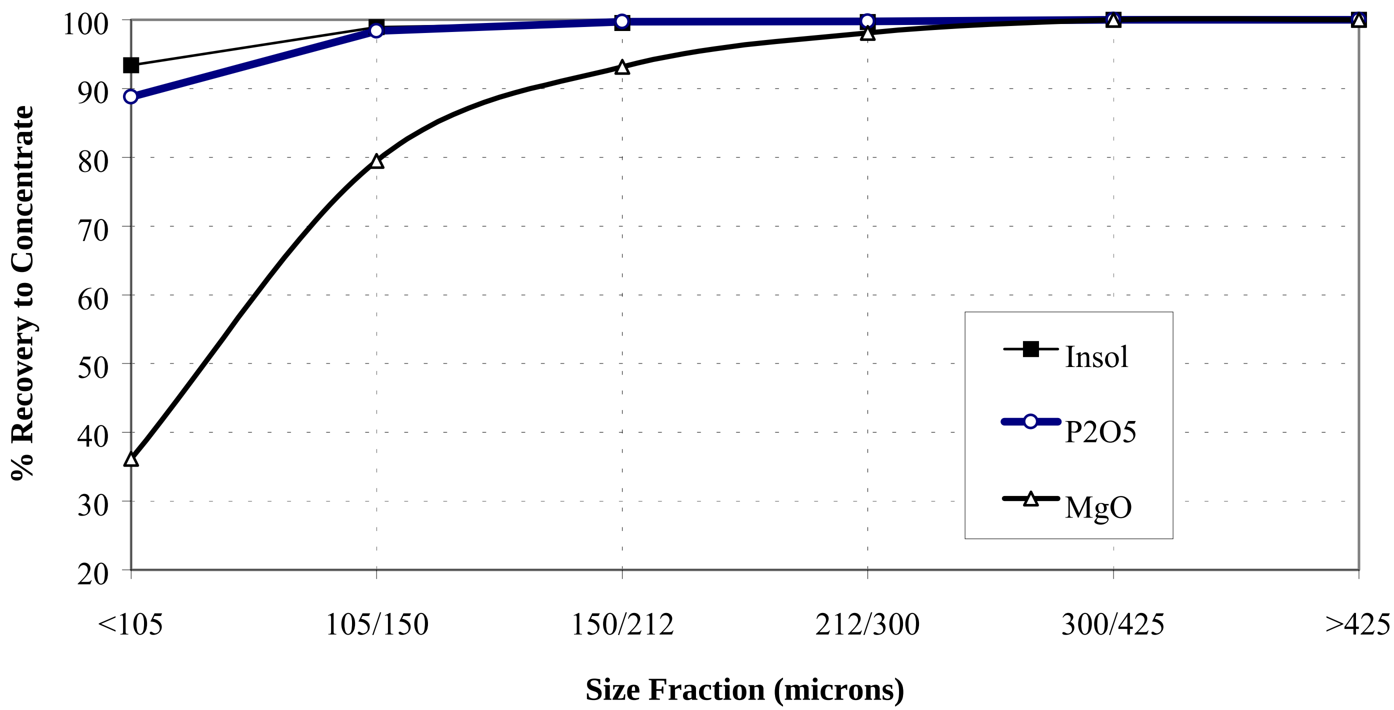


Figure 6. % Recovery vs. Particle Size.

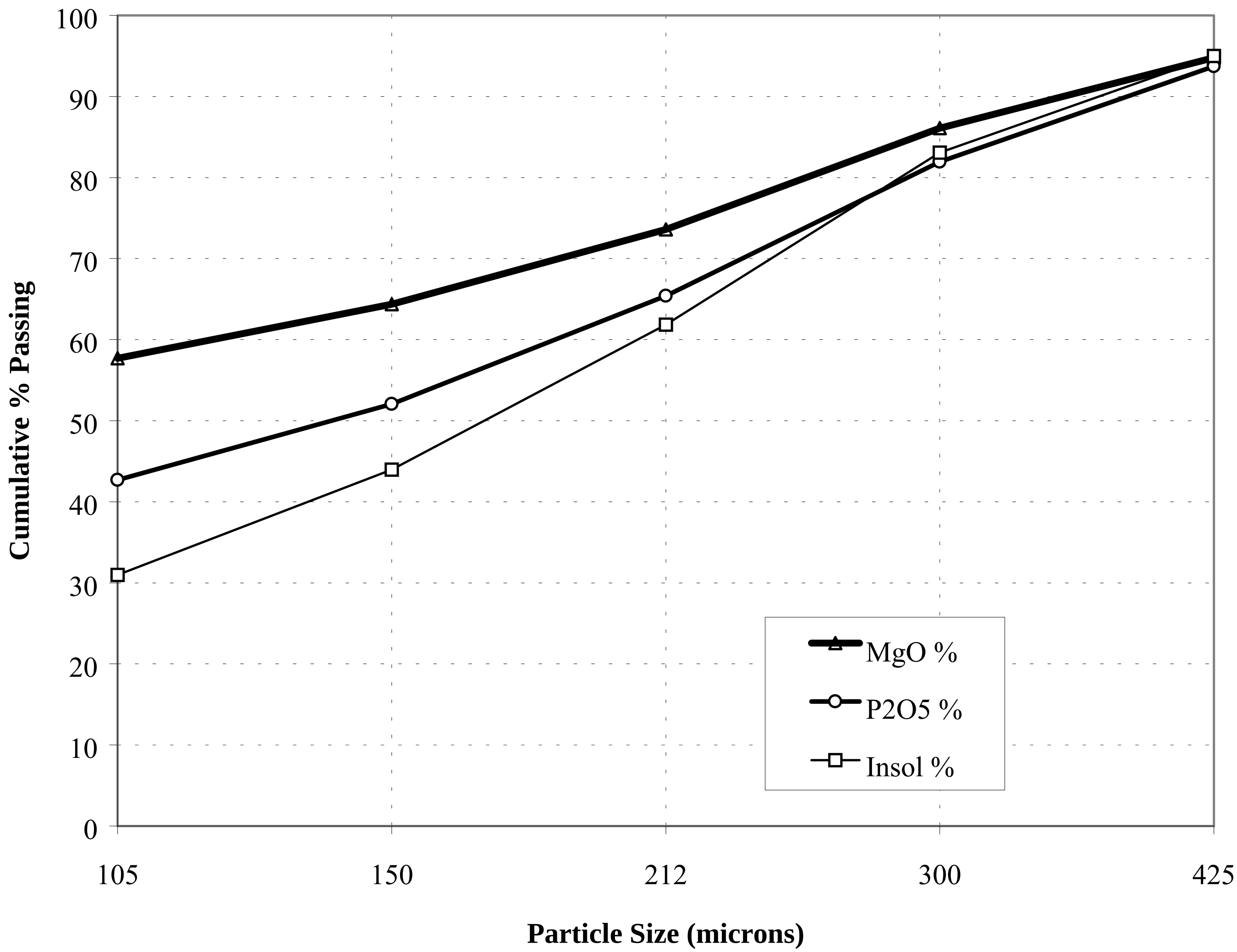


Figure 7. % Distributions vs Particle Size.

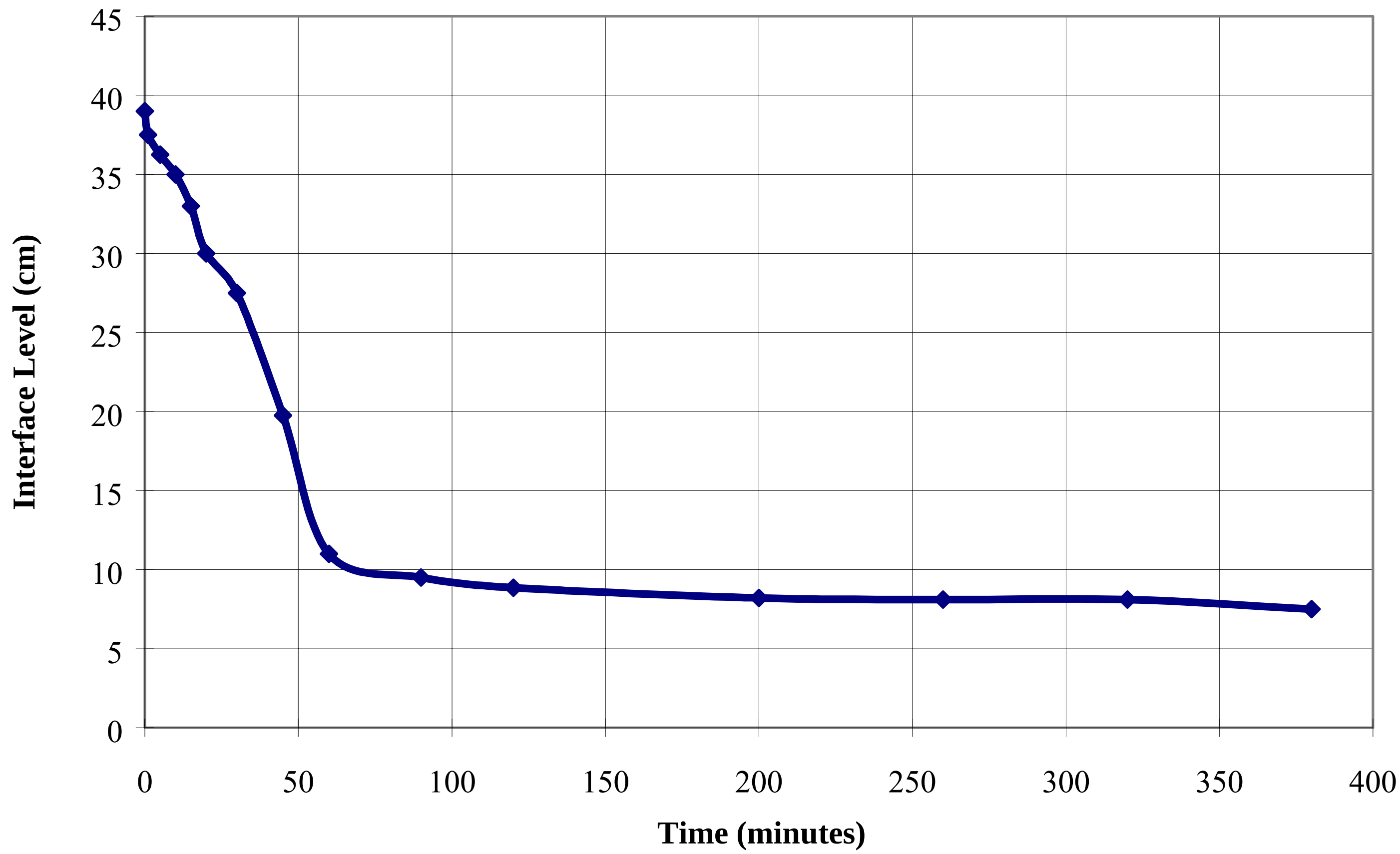


Figure 8. Settling Rate - Concentrate from Test 23.

The two samples of tailings from test 23 were obtained and stored in 2000 ml graduate cylinders for five days. The initial samples were three parts foam and one part slurry by volume. The foam broke down fairly quickly, and was completely dissipated within one hour. Over the five day period, the pH of the slurry increased from 5.05 to 5.65, as measured by the laboratory pH meter. The pH of the flotation cell water, as measured by the pilot plant pH meter, was 5.48. The tailings water and the cell water should have the same pH and the discrepancy between 5.05 and 5.48 is attributed to the use of different pH meters.

Samples of laboratory tap water, pH modifier (Zephyrhills pond water) and cell water from test 23) were analyzed and the results are given in Table 32. Table 32 also shows the combining weights of tap water, pond water, and STPP and the calculated composite analyses.

Table 32. Water Analyses - Pilot Plant Once Through.

	Tap Water	Pond Water	STPP	Calculated Composite	Cell Water
flowrate[1] component (ppm)	574.84	10.32	0.12	585.28	585.15
P_2O_5	1.0	15,900	28,462	287	134
CaO	71	2,500	n/a	114	74
MgO	16	600	n/a	26	34
F	0.9	8,300	n/a	147	40
SO_4	42	8,200	n/a	186	140
pH	7.70	1.22	--	--	6.41
Redox	--	259	--	--	--

(1) kg/h from test 23

Based on the comparison of the calculated water (composite) analysis with the actual analysis of the cell water, it appears that P_2O_5, CaO , and F were precipitated due to the elevated pH, and that some MgO was dissolved from the rock. For comparative purposes the analyses of cell water from the four locked cycle flotation tests are presented in Table 33. The data in Table 33 are more realistic for a closed water system, and show increased concentrations of P_2O_5, CaO, and SO_4 in the cell water relative to once through water.

Table 33. Water Analyses - Laboratory Locked Cycle.

	Scrubbed Pebble		Unscrubbed Pebble	
Component (ppm)	SPPW(1)	ZHPW(2)	SPPW(1)	ZHPW(2)
P_2O_5	300	411	250	410
CaO	163	208	120	190
MgO	30	41	32	43
F	35	25	36	28
SO_4	384	600	384	624

(1) South Pierce Pond Water
(2) Zephyrhills Pond Water

TASK 6

The process tested in this program would be performed at a phosphoric acid plant to remove minor elements and CaO from the reactor feed. All reactor feed could be treated, or alternatively, only the so called waste pebble component of the reactor feed could be treated. For purposes of evaluation, a basis of comparison must be assumed.

Basis

The assumed basis of comparison is a hypothetical phosphate mine and chemical plant. Phosphate ore reserves at the hypothetical mine underlay 1600 mineable acres which yield 12.45 million tons of standard phosphate rock and 4.15 million tons of low-grade pebble. The phosphate rock produced is dedicated to a phosphoric acid plant producing 1000 tons per day (tpd) of P_2O_5. The phosphoric acid is converted to diammonium phosphate (DAP).

Characteristics of the hypothetical ore reserves are summarized in Table 34. The demands for standard rock and low-grade pebble for three production scenarios are presented in Table 35 along with the corresponding process losses and upgraded reactor feed.

In scenario one (standard case), only the upper zone ore is mined and the standard phosphate rock is ground and fed directly to the reactor. In scenario two (base case), the upper and lower zone ore are mined and the combined product is ground in existing milling equipment, floated to remove carbonate gangue, thickened, and then fed to the reactor. In scenario three (alternate case), the upper and lower zones are mined but the standard rock (concentrate) and low-grade pebble are segregated. The concentrate is ground in existing milling equipment, blended with thickened concentrate obtained from low-grade pebble, and then fed to the reactor. Only the low-grade pebble is beneficiated. The pebble treatment comprises scrubbing, desliming, grinding in a new mill, flotation to remove carbonates, and thickening. In each scenario the reactor feed contains nominally 1,075 tons per day of P_2O_5, and phosphoric acid containing 1,000 tpd of P_2O_5 is produced.

Table 34. Hypothetical Ore Reserves.

	Standard Rock[(1)]	Low-Grade Pebble[(2)]	Combined Product[(3)]
Product Analyses			
% P_2O_5	28.50	26.70	28. 05
% Insol.	10.00	13.00	10.75
% CaO	42.75	41.50	42.44
% MgO	0.75	1.32	0.89
% I&A	2.10	2.15	2.11
CaO:P_2O_5	1.500	1.554	1.513
MER	0.100	0.130	0.107
Yd^3/Product Ton			
overburden	4.00	n/a	3.00
ore	4.30	n/a	4.03
Product Tons/Acre	7,500	2,500	10,000

(1) combined product from selectively mined upper zone ore, or concentrate from collectively mined upper and lower zones.
(2) pebble from collectively mined upper and lower zones.
(3) combined product from collectively mined upper and lower zones.

Table 35. Hypothetical Production Scenarios.

Tons/Day - Phosphate Rock[1]	Standard	Base	Alternate
standard rock	3,773	3,033	2,957
low-grade pebble	0	1,011	986
subtotal	3,773	4,044	3,943
process losses	0	(288)[2]	(153)[3]
reactor feed	3,773	3,756	3,790
Reactor Feed Analyses			
% P_2O_5	28.50	28.63	28.37
% Insol.	10.00	11.28	10.73
% CaO	42.75	42.78	42.69
% MgO	0.75	0.66	0.74
% Al_2O_3 + % Fe_2O_3	2.10	2.01	2.06
$CaO:P_2O_5$	1.500	1.494	1.505
MER	0.100	0.0932	0.099
Phosphate Rock, tpy[4]	1,245,090	1,334,520	1,301,190
Years of Operation[5]	10.00	12.44	12.76

(1) rounded to nearest whole ton
(2) process losses are tailings from flotation of 4044 tpd
(3) process losses are from desliming and flotation of 986 tpd
(4) subtotal tpd x 330 days/yr.
(5) reserves tons/tpy

The extended years of operation for the base and alternate cases are possible because mining both the upper and lower zones increased product recovery from the existing reserves.

Process Description

1. Base Case. The waste pebble is blended with the regular rock. The blend is fed to existing ball mills, and ground to pass 28 mesh. The solids content of the grinding slurry is controlled at 67% by adding pond water and recycle water according to a ratio of 1 to 6. The ground slurry is pumped to reagent conditioners. Sodium tripolyphosphate (STPP) solution, collector and more pond water are added to the conditioners. The slurry is conditioned at 65% solids. After conditioning, the slurry is transferred to flotation cells where it is diluted to 16% solids for flotation of carbonates using a combination of fresh and recycle waters. The pH of the slurry is maintained at pH 5.5 by the addition of pond water. The carbonates are floated. Carbonate tailings, the froth product, are pumped to a carbonate tailings disposal area where they are dewatered to 40% solids. The concentrate, the cell product, is transported to a thickener using pumps. The overflow of the thickener is combined with the return water from the carbonate tailings disposal area, and used as recycle water in the process. The thickener underflow at 68% solids is fed to the reactor feed tanks of the phosphoric acid plant. The base case is illustrated in Figure 9.

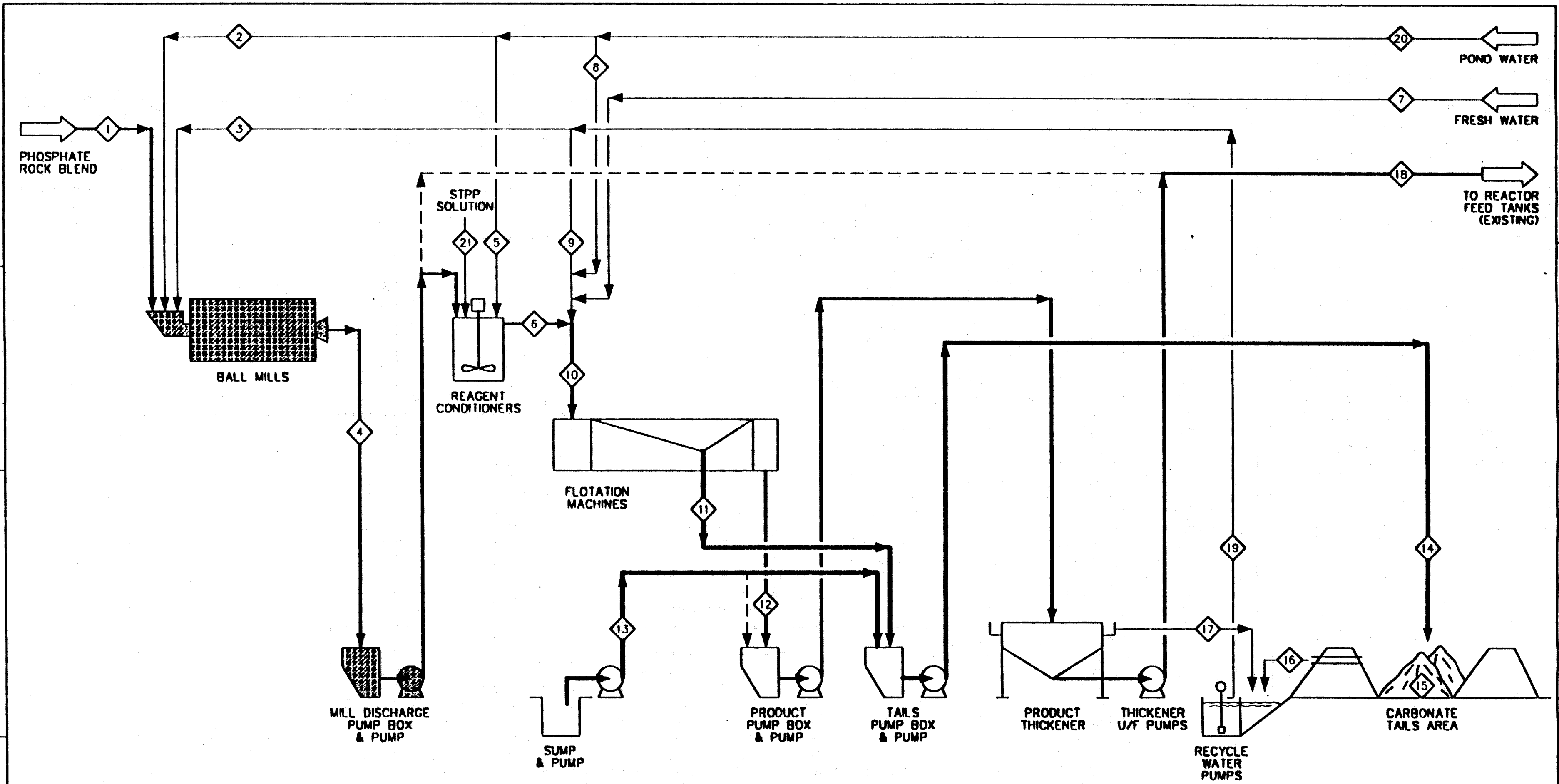
2. Alternate Case. Only the waste pebble is beneficiated. The waste pebble is conveyed to a pebble surge bin. It is fed via a belt scale to a log washer and diluted with recycle water. Most of the clays are rejected in the log washer. The log washer coarse product at 75% solids is discharged to a Vertimill. The pond water and recycle water are used to make a 67.8% solids slurry, which is ground to pass 28 mesh. The ground slurry is pumped to reagent conditioners. Sodium tripolyphosphate (STPP) solution, collector and more pond water are added to the conditioners. The slurry is conditioned at 65% solids. After conditioning, the slurry is introduced to flotation cells where it is diluted to 16% solids for flotation of carbonates using fresh and recycle waters. The pH of the slurry is maintained at pH 5.5 by the addition of pond water. The carbonates are floated. Carbonate tailings, the froth product, are pumped to a carbonate tailings disposal area where they are dewatered to 40% solids. The concentrate, the cell product, is pumped to a thickener. The overflow of the thickener is combined with the return water from the carbonate tailings disposal area, and used as recycle water in the process. The thickener underflow, the flotation concentrate, is combined with the regular rock. The blend is pumped to the reactor feed tanks of the phosphoric acid plant. The alternate case is shown in Figure 10.

Capital Cost Estimates

No equipment or construction is required for the standard case. The material balances and new equipment items for the base case and alternate case are shown in Figures 9 and 10, respectively. Equipment lists for these two cases are provided in Appendix B.

The capital cost estimates were factored from priced process equipment, based on Jacobs' in-house files. Constructed costs for the base and alternate cases were estimated at $6.5 million and $7.1 million, respectively. Components of these estimates are summarized in Table 36. The estimates are based on present day pricing with no forward escalation included.

The constructed costs are comprised of direct costs, indirect costs, professional services costs and include a ten percent allowance for unforeseen costs and a four percent contractors fee.



STREAM NUMBER

DESCRIPTION	1	2	3	4	5	6	7	8	9	10	11
TPH (SOLIDS)	168.48	0	0	168.48	0	168.48	0	0	0	168.48	12.00
% SOLIDS	88.0	0	0	67.0	0	65.5	0	0	0	16.0	4.5
GPM (WATER)	91.90	33.92	203.64	329.45	14.21	351.55	198.25	17.76	2945.30	3512.86	1009.06
GPM (PULP)	332.59	33.92	203.64	570.14	14.21	592.24	198.25	17.76	2945.30	3753.55	1026.19
SP. GR. (PULP)	2.303	1.030	1.007	1.757	1.030	1.727	1.000	1.030	1.007	1.115	1.030
TPH - P_2O_5 ROCK	47.26	0.00	0.00	47.26	0.00	47.26	0.00	0.00	0.00	47.26	2.46
TPH - P_2O_5 SOLN	0.00	0.14	0.02	0.16	0.06	0.28	0.00	0.07	0.30	0.037	0.11
TPH - P_2O_5 PPT	.	.	.	.	.	.	.	.	.	0.29	0.09
TPH - P_2O_5 TOTAL	47.26	0.14	0.02	47.42	0.06	47.54	0.00	0.07	0.30	47.92	2.66
MgO TPH	1.50	0.01	0.00	1.51	0.00	1.51	0.00	0.00	0.03	1.54	0.48
CaO TPH	71.51	0.02	0.01	71.54	0.01	71.55	0.00	0.01	0.15	71.72	4.61

DESCRIPTION	12	13	14	15	16	17	18	19	20	21
TPH (SOLIDS)	156.49		12.00	12.00	0	0	156.49	0	0	0
% SOLIDS	20.0		4.5	40.0	0	0	68.0	0	0	0
GPM (WATER)	2503.80		1009.06	71.46	937.60	2211.34	292.46	3148.94	65.88	7.89
GPM (PULP)	2727.35		1026.19	88.60	937.60	2211.34	516.01	3148.94	65.88	7.89
SP. GR. (PULP)	1.148	1.000	1.030	1.346	1.007	1.007	1.777	1.007	1.030	1.082
TPH - P_2O_5 ROCK	44.80		2.46	2.46	0.00	0.00	44.80	0.00	0.00	0.00
TPH - P_2O_5 SOLN	0.26		0.11	0.01	0.10	0.23	0.03	0.33	0.27	0.06
TPH - P_2O_5 PPT	0.20		0.09	0.09	.	.	0.20	.	.	.
TPH - P_2O_5 TOTAL	45.26		2.66	2.56	0.10	0.23	45.03	0.33	0.27	0.06
MgO TPH	1.06		0.48	0.47	0.01	0.02	1.04	0.03	0.01	0.00
CaO TPH	67.08		4.61	4.56	0.05	0.11	66.96	0.16	0.04	0.00

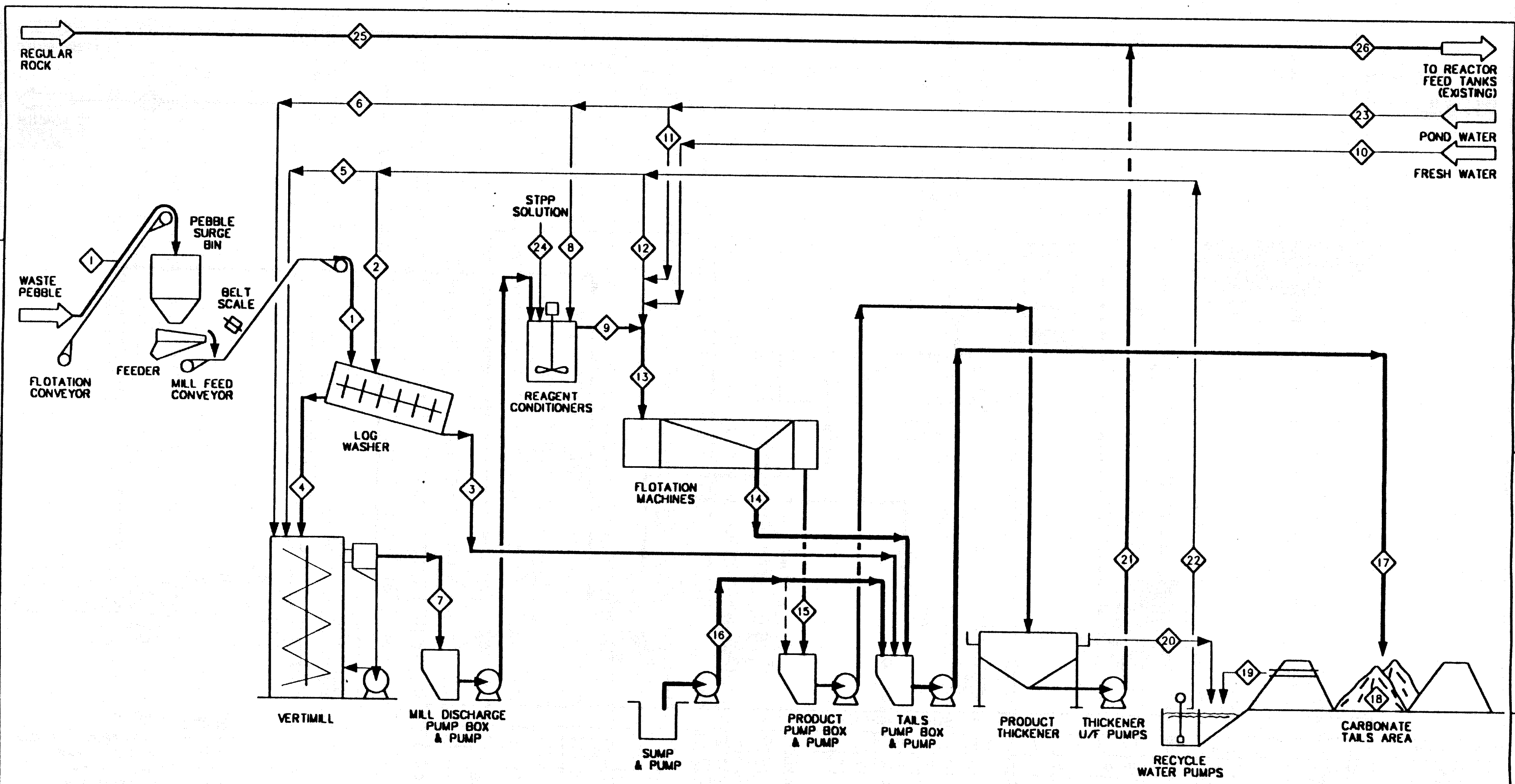
EXISTING
MAJOR PROCESS STREAM
PROCESS STREAM
WATER STREAM
ALTERNATE FLOW

JE JACOBS ENGINEERING GROUP INC.
LAKELAND FLORIDA

PHOSPHATE ROCK TREATMENT FOR WASTE REDUCTION
FIPR CONTRACT No. 93-01-112R
BASE CASE
CONCEPTUAL FLOTATION PROCESS PFD

PREPARED BY MEK	DRAWN BY CMP
DATE: 11-23-98	CADD NO. 925K0018

SCALE	ORDER NO.	DRAWING NO.	REV
NONE	28-P925-00	FIGURE 9	



DESCRIPTION	STREAM NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13
TPH (SOLIDS)	41.08	0	3.20	37.87	0	0	37.87	0	37.87	0	0	0	37.87
% SOLIDS	88.00	0	6.90	75.00	0	0	67.80	0	66.28	0	0	0	16.00
GPM (WATER)	22.40	200.00	171.91	50.49	13.69	7.52	71.71	3.15	76.61	64.24	3.94	646.26	791.04
GPM (PULP)	81.08	200.00	176.49	104.60	13.69	7.52	125.81	3.15	130.71	64.24	3.94	646.26	845.14
SP. GR. (PULP)	2.303	1.006	1.053	1.931	1.006	1.030	1.776	1.030	1.749	1.000	1.030	1.006	1.120
TPH – P_2O_5 ROCK	10.97	0.00	0.73	10.24	0.00	0.00	10.24	0.00	10.24	0.00	0.00	0.00	10.24
TPH – P_2O_5 SOLN	0.00	0.02	0.02	0.00	0.00	0.03	0.04	0.01	0.06	0.00	0.02	0.07	0.09
TPH – P_2O_5 PPT	.	.	.	.	.	.	.	.	.	.	.	.	0.06
TPH – P_2O_5 TOTAL	10.97	0.02	0.75	10.24	0.00	0.03	10.27	0.01	10.30	0.00	0.02	0.07	10.38
MgO TPH	0.54	0.00	0.09	0.45	0.00	0.00	0.46	0.00	0.46	0.00	0.00	0.01	0.46
CaO TPH	17.05	0.01	1.30	15.76	0.00	0.00	15.76	0.00	15.76	0.00	0.00	0.03	15.80

DESCRIPTION	14	15	16	17	18	19	20	21	22	23	24	25	26
TPH (SOLIDS)	3.18	34.70	0	6.38	6.38	0	0	34.70	0	0	0	123.23	157.92
% SOLIDS	5.02	20.00	0	5.82	40.00	0	0	68.00	0	0	0	68.00	68.00
GPM (WATER)	235.91	555.13	0	407.82	38.06	369.76	490.19	64.94	859.95	14.61	1.75	231.95	296.89
GPM (PULP)	240.44	604.70	0	416.93	47.17	369.76	490.19	114.51	859.95	14.61	1.75	407.99	522.50
SP. GR. (PULP)	1.052	1.148	1.000	1.052	1.352	1.006	1.006	1.782	1.006	1.030	1.082	1.777	1.778
TPH – P_2O_5 ROCK	0.55	9.68	0	1.28	1.28	0.00	0.00	9.68	0.00	0.00	0.00	35.12	44.80
TPH – P_2O_5 SOLN	0.03	0.06	0	0.04	0.00	0.04	0.05	0.01	0.09	0.06	0.01	0.00	0.01
TPH – P_2O_5 PPT	0.02	0.04	.	0.02	0.02	.	.	0.04	.	.	.	.	0.04
TPH – P_2O_5 TOTAL	0.60	9.78	0	1.35	1.31	0.04	0.05	9.73	0.09	0.06	0.01	35.12	44.85
MgO TPH	0.22	0.25	0	0.30	0.30	0.00	0.01	0.24	0.01	0.00	0.00	0.93	1.17
CaO TPH	1.03	14.76	0	2.34	2.32	0.02	0.03	14.74	0.05	0.01	0.00	52.69	67.42

MAJOR PROCESS STREAM
PROCESS STREAM
WATER STREAM
ALTERNATE FLOW

JACOBS ENGINEERING GROUP INC.
LAKELAND FLORIDA

PHOSPHATE ROCK TREATMENT FOR WASTE REDUCTION
FIPR CONTRACT No. 93-01-112R
ALTERNATE
CONCEPTUAL FLOTATION PROCESS PFD

PREPARED BY MEK | DRAWN BY CMP
DATE: | CADD NO.
SCALE NONE | 28-P925-00 | FIGURE 10

Direct costs include major process equipment, labor, subcontractors and equipment required for erection and installation. The labor component includes craft labor and supervision, but excludes fringes. Direct costs also include bulk commodity materials (concrete, piping structural steel, etc.), subcontracts (electrical supplies, paint, insulation, etc.) and construction labor for erection and installation. Construction of the carbonate tailings area is included.

Indirect costs include construction service labor, temporary facilities, craft fringes, payroll taxes and insurance, construction equipment, field staff and expenses.

Other costs include professional services, expenses and contractors fee for engineering, procurement and construction. An allowance of ten percent for unforeseen costs has been added to the estimate due to the conceptual nature of the scope definition.

Exclusions. Items excluded from the estimated capital costs are:

- value for land
- permitting and other development costs
- inflation and escalation
- interest during construction
- start-up costs
- working capital
- all risk insurance
- liner for carbonate tailings settling area.

Operating Cost Estimates

Three scenarios for the hypothetical operation are considered in this evaluation. For each scenario, the costs of producing phosphate rock, transporting rock from the mine to the chemical plant, and upgrading the rock at the chemical plant are estimated.

Estimates of FOB rock production costs for each scenario are presented in Appendix C and summarized in Table 37. Estimated freight costs are also shown in Table 37.

Table 36. Estimated Capital Costs - Summary[(1)].

Direct Costs	Base Case	Alternate Case
process equipment	1,119,000	1,593,000
bulk materials	1,398,000	1,349,000
labor	771,000	706,000
subcontracts	659,000	818,000
subtotal	3,947,000	4,466,000
Indirect Costs		
field indirects	963,000	882,000
home office	670,000	729,000
subtotal	1,633,000	1,611,000
Other Costs		
sales tax	164,000	189,000
contingency	575,000	626,000
contractors fee	196,000	214,000
subtotal	935,000	1,029,000
Total Installed Cost	$6,515,000	$7,106,000

(1) Date of estimates is January 1, 1999. The capital costs are for adding beneficiation modules to a hypothetical 1000 tpd phosphoric acid plant.

Table 37. Phosphate Rock Delivered Cost Estimate.

	Standard Case	Base Case	Alternate Case
FOB Cost ($/ton)	21.81	20.34	20.58
Transportation Cost ($/ton)	2.50	2.50	2.50
Delivered Cost ($/ton)	24.31	22.84	23.08
Ton Rock/Yr.	1,245,090	1,334,520	1,301,190
Delivered Cost ($/yr)	30,268,000	30,480,000	30,031,000

The unit costs for the base and alternate cases are lower than the standard case because more rock is recovered per acre of reserves, and no rock is rejected at the beneficiation plant.

Beneficiation costs to upgrade the rock at the chemical plant are estimated in Table 38 for the base and alternate cases. No beneficiation is required for the standard case. The basis for estimating the direct operating costs is given on the page following.

Table 38. Beneficiation Module Direct Operating Cost Summary.

Dollars Per Year	Base Case	Alternate Case
Labor Costs	237,000	395,000
Supplies	271,000	308,000
Flotation Reagents	3,421,000	758,000
Electrical	250,000	174,000
Dam Construction	24,000	13,000
Total Direct Cost	4,203,000	1,648,000

Operating labor is based on one operator per shift and one reagent man for the base case and two operators per shift and one reagent man for the alternate case. Maintenance labor is based on one person per year for each case. Supplies are estimated as the sum of six percent of labor costs and four percent of capital cost. Flotation reagents are based on 110% of consumptions from test 23 and unit prices of \$0.95/kg for STPP, \$0.66/kg for collector, and \$0.22/kg for diesel oil. Electrical costs are factored from connected horsepower, except that no change in grinding power is assumed.

The major influence on operating cost is flotation reagents and the amount of reactor feed treated by flotation. In the base case, all reactor feed is treated by flotation; whereas, in the alternate case only 22 percent of the reactor feed is produced by flotation.

The costs of reactor feed for the three production scenarios are presented in Table 39. The estimated costs take into account recovery losses.

Table 39. Estimated Annual Cost of Reactor Feed[(1)].

Cost per Year	Standard Case	Base Case	Alternate Case
Delivered Rock	30,268,000	30,480,000	30,031,000
Beneficiation Module	0	4,203,000	1,648,000
Total Cost	30,268,000	34,683,000	31,679,000
Cost per Ton			
Reactor Feed Solids	24.31	27.98	25.33
Reactor Feed P_2O_5[(2)]	91.72	105.09	96.00

(1) grinding costs are incorporated in the estimated phosphoric acid production costs.

(2) 330,000 tons P_2O_5 per year

The production costs to convert the reactor feed to phosphoric acid and then produce 18:46:0 DAP are summarized in Table 40 and estimate sheets are included with Attachment C. They include the use of urea to make DAP grade.

Table 40. Estimated DAP Production Costs - Summary[1].

Cost Element	Standard Case	Base Case	Alternate Case
Raw Materials	103.04	103.77	105.15
Electricity	4.25	4.23	4.26
Fuel	.78	.77	.78
Reagents	1.66	1.65	1.66
Labor	5.43	5.40	5.44
Other Processing	1.06	1.03	1.10
Capital Charges	27.94	27.81	28.00
Total Cost FOB Plant	144.16	144.66	146.39

(1) Estimate basis is January 1999. January 1999 costs for raw materials and other operating cost elements were used.

Assuming the FOB sales price of DAP is $175 per ton, the margin per ton of DAP for the standard, base, and alternate cases are $30.84, $30.34 and $28.61, respectively. Table 41 shows the annual profit margins for each scenario. In the short term, improved profit margins are obtained from the standard case; however, as shown in Table 42, the standard case is less profitable over the long term than the base or alternate cases.

Table 41. Estimated DAP Margins.

	Standard Case	Base Case	Alternate Case
Sales Price ($/Ton)	175.00	175.00	175.00
Production Cost ($/Ton)	144.16	144.66	146.39
Margin ($/Ton)	30.84	30.34	28.61
Tons DAP/Yr.	690,186	690,186	690,186
Margin $/Yr.	21,285,336	20,940,243	19,746,221

Over the thirteen-year life of the hypothetical reserve, the base and alternate cases increase before tax profit margins by 43 and 37 million dollars, respectively. Taking into account the present value of money at an eight percent discount rate, the total before tax profit margins are reduced to 18 and 14 million dollars, respectively.

Incremental analysis of the base case and alternate case indicate that their capital investments have 17 and 11 percent internal rates of return, respectively, without tax impacts.

The base case, where all reactor feed is beneficiated, is more economically attractive than the alternate case because the capital cost is less, and the profit margin per ton of DAP is higher.

In year one of this study, production costs were estimated for converting low-grade phosphate rock to DAP with and without flotation treatment of the reactor feed. Flotation reduced the MER of the filter acid from 0.119 to 0.097 and reduced the consumption of H_2SO_4 by about three percent. As a consequence of improving the MER and reducing the H_2SO_4 consumption, flotation of the reactor feed resulted in a savings of seven dollars per ton of DAP.

Table 42. Preliminary Economics.

$ Investment and Total Margins			Incremental Analyses[1]	
Standard Case	Base Case	Alt.Case	Base Case[2]	Alt.Case[3]
-	(6,515,000)	(7,106,000)	(6,515,000)	(7,106,000)
21,285,336	20,940,234	19,746,221	(345,102)	(1,539,115)
21,285,336	20,940,234	19,746,221	(345,102)	(1,539,115)
21,285,336	20,940,234	19,746,221	(345,102)	(1,539,115)
21,285,336	20,940,234	19,746,221	(345,102)	(1,539,115)
21,285,336	20,940,234	19,746,221	(345,102)	(1,539,115)
21,285,336	20,940,234	19,746,221	(345,102)	(1,539,115)
21,285,336	20,940,234	19,746,221	(345,102)	(1,539,115)
21,285,336	20,940,234	19,746,221	(345,102)	(1,539,115)
21,285,336	20,940,234	19,746,221	(345,102)	(1,539,115)
21,285,336	20,940,234	19,746,221	(345,102)	(1,539,115)
-	20,940,234	19,746,221	20,940,234	19,746,221
-	20,940,234	19,746,221	20,940,234	19,746,221
-	9,214,000	15,017,000	9,214,000	15,017,000
212,853,360	253,981,808	244,865,652	41,128,448	32,012,292
$142,826,337	$159,823,719	$155,607,692	$16,997,381	$12,781,354
na	na	na	17%	11%

(1) Analyses do not include inflation or tax impacts.
(2) Annual values = Base Case - Standard Case
(3) Annual values = Alternate Case - Standard Case
NPV = net present value, IRR = internal rate of return

CONCLUSIONS

The carbonate rejection process has shown the potential for economic improvement in the production of wet process phosphoric acid from marginal phosphate rock. The four areas of potential improvement that were demonstrated by testwork done on this project are:

- increased consumption of pond water
- reduction in the production of phosphogypsum
- lower overall cost of DAP
- extension of mineable reserves by increased production from a given mining area

The pond water consumption would be on the order of 90,000 gallons per day in the base case and 20,000 gallons per day in the alternate case. Unlike the pond water currently used in wet rock grinding, the pond water used in the beneficiation module would be removed from the chemical plant water system. This provides a means of avoiding excessive inventory of 1.5 pH pond water during high rainfall events. The water from the carbonate tailings disposal area would be expected to have a pH of more than 5.5 and the cost of treating and releasing this water would be a fraction of the cost of treating a similar volume of 1.5 pH pond water. Some of the P_2O_5 from the pond water appears to precipitate with a percentage being recovered with the product.

In tests using rock of the same quality, the $CaO:P_2O_5$ ratio was reduced by between 2 and 6 percent by carbonate flotation versus no pretreatment. This would produce a commensurate reduction in the production of phosphogypsum. The MER ratios were also improved by between 13 and 30 percent. However, the greatest improvements in $CaO:P_2O_5$ and MER occurred with the lowest P_2O_5 recovery. The potential of the process is evident, but room for improvement exists.

The impact of the improvement in rock quality is best shown when viewed as a function of DAP cost. The DAPCOST model used in this analysis includes sulfuric acid consumption and capacity restrictions based on the $CaO:P_2O_5$ ratio, as well as the impact of high MER on the production of DAP. The individual characteristics of some phosphate rocks will make them more suitable for this process than others, but as MgO levels increase the merit of this type of process will also be enhanced.

The fourth area of potential for this process is in the ability to extend the life of a given reserve by mining lower grade material than would be mined by today's standards and using the carbonate rejection process to upgrade the resulting product. In our hypothetical scenario, the life of the reserve was extended by 24 percent in the base case and 28 percent in the alternate case. The overall economics favored the base case over both the alternate case and the standard case in our analysis. A deposit with a higher percentage of lower zone ore would have an even higher payout. Economics for any specific deposit would require separate examination, and confirmatory testwork on the actual rock should be done prior to embarking upon a production situation.

The economic benefits of reducing DAP production costs and extending reserves life by flotation treatment are not additive. If the decision to maximize reserves and produce a lower quality rock is made, flotation treatment will reduce the amount of P_2O_5 recovered as DAP but reduce the DAP production cost. On the other hand, if the decision is to maintain relatively uniform DAP production costs, flotation treatment will increases the tonnage of lower zone ore reserves that can be exploited.

RECOMMENDATIONS

The research sponsored by FIPR during years one and two of this study has demonstrated that flotation of ground reactor feed to remove calcium and magnesium carbonate as well as some minor elements is technically feasible. The economic feasibility of this treatment is dependent on the characteristics of the ground phosphate rock and the availability of commercial quality phosphate rock.

Grinding devices, such as high pressure grinding rolls, that promote selective grinding of the carbonate gangue would substantially improve the characteristics of the ground phosphate rock for flotation. It is possible that improved recovery of phosphate and greater rejection of carbonates could be obtained.

A program to evaluate carbonate flotation of phosphate rock ground in a high pressure roll would be the logical next step.

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APPENDIX A

REPORT SHEETS FOR PILOT PLANT TESTS 1 TO 23

Appendix A1 Removal of CaO and MgO from Reject Pebble

Data recorded by:	krg, jah, sph	Test Date:	9/15/98	***Test No.*** ***1***
		Print Date:	11/21/98	

Water Usage	water (kg/h)
screen spray water	3052.78
flotation cell dilution	884.00
sparger trim water	113.33
froth launder water	226.67

Reagent Usage	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	7.42	59.38	72.49
pond water to conditioner	0.49	3.96	4.83
pond water to cell	2.47	19.79	24.16
total pond water	10.38	83.13	101.48
STPP	0.16	1.25	1.52
Collector	0.14	1.15	1.41
Frother	0.02	0.12	0.15

	Flow Rate (kg/h)			***Analyses***			
	slurry	liquid	solids	% Solids[1]	% P_2O_5 [2]	% Insol[2]	% MgO[2]
low grade pebble	184.98	60.08	124.90	67.52	26.78	13.02	1.18
screen feed	3237.76	3104.26	133.50	4.12	26.69	12.48	1.13
-400 mesh waste	3059.54	3052.78	6.76	0.22	24.30	9.05	1.18
deslimed pebble	178.22	60.08	118.14	66.29	26.92	13.25	1.18
rod mill discharge	185.63	67.49	118.14	63.64	26.92	13.25	1.18
conditioner discharge	226.92	100.18	126.73	55.85	26.82	12.66	1.12
froth tailing	533.08	508.66	24.42	4.58	27.24	6.20	2.40
cell concentrate	734.43	632.12	102.31	13.93	26.72	14.20	0.82

Cell Operating Parameters	
air - cm/sec	#DIV/0!
air % holdup	0
froth product - cm/sec	0.50
concentrate - cm/sec	0.65

Distributions	Weight %[2]	P_2O_5 %	Insol %	MgO %
low grade pebble	100.00	100.00	100.00	100.00
-400 mesh waste	5.07	4.61	3.68	5.30
froth tailing	18.29	18.67	9.09	38.95
cell concentrate	76.64	76.72	87.23	55.75
Flotation % Recovery	**80.73**	**80.43**	**90.56**	**58.87**

Notes: (1) wet basis, (2) dry basis

Appendix A2 Removal of CaO and MgO from Reject Pebble

Data recorded by:	krg, jah, sph	Test Date:	9/21/98	***Test No.***	***4***
		Print Date:	11/21/98		

Water Usage	
	water (kg/h)
screen spray water	3926.40
flotation cell dilution	884.00
sparger trim water	113.33
froth launder water	226.67

	Reagent Usage		
	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	12.85	98.84	116.12
pond water to conditioner	0.74	5.70	6.70
pond water to cell	1.24	9.50	11.17
total pond water	14.83	114.05	133.99
STPP	0.16	1.20	0.14
Collector	0.17	1.29	1.52
Frother	0.02	0.13	0.15

	Flow Rate (kg/h)			***Analyses***			
	slurry	liquid	solids	% Solids[(1)]	% P_2O_5 [(2)]	% Insol[(2)]	% MgO[(2)]
low grade pebble	225.43	95.38	130.05	57.69	26.39	12.99	1.19
screen feed	4151.83	4015.36	136.48	3.29	26.26	13.16	1.67
-400 mesh waste	3928.61	3926.40	2.21	0.06	22.62	9.68	1.19
deslimed pebble	223.22	95.38	127.84	57.27	26.46	13.05	1.19
rod mill discharge	236.08	108.24	127.84	54.15	26.46	13.05	1.19
conditioner discharge	269.14	134.87	134.27	49.89	26.32	13.22	1.68
froth tailing	533.68	510.10	23.57	4.42	25.97	5.97	5.40
cell concentrate	766.36	655.66	110.70	14.44	26.40	14.76	0.89

Cell Operating Parameters	
air - cm/sec	0.29
air % holdup	0
froth product - cm/sec	0.51
concentrate - cm/sec	0.68

	Distributions			
	Weight %[(2)]	P_2O_5 %	Insol %	MgO %
low grade pebble	100.00	100.00	100.00	100.00
-400 mesh waste	1.62	1.39	1.19	1.15
froth tailing	17.27	17.08	7.84	55.72
cell concentrate	81.11	81.53	90.97	43.13
Flotation % Recovery	**82.44**	**82.68**	**92.07**	**43.63**

Notes: (1) wet basis, (2) dry basis

Appendix A3 Removal of CaO and MgO from Reject Pebble

Data recorded by:	krg, jah, sph	Test Date:	9/21/98	***Test No.***	*5*
		Print Date:	11/21/98		

Water Usage	
	water (kg/h)
screen spray water	4023.91
flotation cell dilution	884.00
sparger trim water	113.33
froth launder water	226.67

	Reagent Usage		
	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	8.65	50.81	64.58
pond water to conditioner	0.74	4.36	5.54
pond water to cell	1.55	9.07	11.53
total pond water	10.94	64.24	81.64
STPP	0.14	0.84	1.07
Collector	0.14	0.81	1.03
Frother	0.02	0.10	0.13

	Flow Rate (kg/h)			***Analyses***			
	slurry	liquid	solids	% Solids(1)	% P_2O_5 (2)	% Insol(2)	% MgO(2)
low grade pebble	298.67	128.39	170.28	57.01	26.27	13.23	1.18
screen feed	4322.57	4166.09	156.49	3.62	26.34	13.23	1.61
-400 mesh waste	4028.00	4023.91	4.09	0.10	23.05	10.52	1.18
deslimed pebble	294.58	128.39	166.19	56.42	26.35	13.30	1.18
rod mill discharge	303.23	137.04	166.19	54.81	26.35	13.30	1.18
conditioner discharge	480.67	328.27	152.40	31.71	26.43	13.30	1.62
froth tailing	792.06	773.64	18.42	2.33	24.67	6.06	6.50
cell concentrate	864.19	730.21	133.98	15.50	26.67	14.30	0.95

Cell Operating Parameters	
air - cm/sec	0.29
air % holdup	0
froth product - cm/sec	0.76
concentrate - cm/sec	0.76

	Distributions			
	Weight %(2)	P_2O_5 %	Insol %	MgO %
low grade pebble	100.00	100.00	100.00	100.00
-400 mesh waste	2.61	2.29	2.08	1.92
froth tailing	11.77	11.02	5.39	47.54
cell concentrate	85.62	86.69	92.53	50.54
Flotation % Recovery	**87.91**	**88.72**	**94.50**	**51.53**

Notes: (1) wet basis, (2) dry basis

Appendix A4 Removal of CaO and MgO from Reject Pebble

Data recorded by:	krg, jah, sph	Test Date:	9/23/98
		Print Date:	11/21/98
		Test No.	***6***

Water Usage	water (kg/h)
screen spray water	4134.51
flotation cell dilution	1110.67
sparger trim water	113.33
froth launder water	0.00

Reagent Usage	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	10.88	84.81	100.18
pond water to conditioner	0.62	4.82	5.69
pond water to cell	1.85	14.46	17.08
total pond water	13.35	104.09	122.94
STPP	0.17	1.32	1.55
Collector	0.13	1.03	1.22
Frother	0.02	0.13	0.15

	Flow Rate (kg/h)			***Analyses***			
	slurry	liquid	solids	% Solids[1]	% P_2O_5 [2]	% Insol[2]	% MgO[2]
low grade pebble	204.23	75.98	128.25	62.79	26.68	13.00	1.12
screen feed	4338.74	4205.70	133.04	3.07	26.44	13.26	1.58
-400 mesh waste	4136.17	4134.51	1.66	0.04	22.95	11.52	1.12
deslimed pebble	202.57	75.98	126.59	62.49	26.73	13.02	1.12
rod mill discharge	213.45	86.86	126.59	59.31	26.73	13.02	1.12
conditioner discharge	169.44	38.06	131.38	77.54	26.49	13.28	1.59
froth tailing	476.91	454.10	22.80	4.78	26.13	6.86	5.20
cell concentrate	873.76	765.18	108.58	12.43	26.56	14.63	0.83

Cell Operating Parameters	
air - cm/sec	0.29
air % holdup	0
froth product - cm/sec	0.45
concentrate - cm/sec	0.78

Distributions	Weight %[2]	P_2O_5 %	Insol %	MgO %
low grade pebble	100.00	100.00	100.00	100.00
-400 mesh waste	1.25	1.08	1.08	0.88
froth tailing	17.14	16.94	8.87	56.32
cell concentrate	81.61	81.98	90.05	42.80
Flotation % Recovery	**82.64**	**82.88**	**91.03**	**43.18**

Notes: (1) wet basis, (2) dry basis

Appendix A5 Removal of CaO and MgO from Reject Pebble

Data recorded by:	krg, jah, sph	Test Date:	9/23/98
		Print Date:	11/21/98
Test No.	*7*		

Water Usage	water (kg/h)
screen spray water	4143.80
flotation cell dilution	1110.67
sparger trim water	113.33
froth launder water	0.00

Reagent Usage	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	10.82	101.28	151.52
pond water to conditioner	0.62	5.79	8.66
pond water to cell	2.47	23.15	34.63
total pond water	13.91	130.22	194.81
STPP	0.17	1.58	2.36
Collector	0.14	1.29	1.93
Frother	0.02	0.15	0.22

	Flow Rate (kg/h)			***Analyses***			
	slurry	liquid	solids	% Solids[1]	% P_2O_5 [2]	% Insol[2]	% MgO[2]
low grade pebble	182.25	75.47	106.78	58.59	26.53	13.09	1.14
screen feed	4326.05	4230.82	95.23	2.20	26.69	13.09	1.73
-400 mesh waste	4144.53	4143.80	0.73	0.02	22.89	11.72	1.14
deslimed pebble	181.52	75.47	106.05	58.42	26.56	13.10	1.14
rod mill discharge	192.33	86.28	106.05	55.14	26.56	13.10	1.14
conditioner discharge	174.74	80.23	94.50	54.08	26.72	13.10	1.74
froth tailing	507.70	484.57	23.12	4.55	26.67	6.76	4.60
cell concentrate	875.30	803.92	71.38	8.15	26.73	15.15	0.81

Cell Operating Parameters	
air - cm/sec	0.29
air % holdup	0
froth product - cm/sec	0.48
concentrate - cm/sec	0.81

Distributions	Weight %[2]	P_2O_5 %	Insol %	MgO %
low grade pebble	100.00	100.00	100.00	100.00
-400 mesh waste	0.76	0.66	0.68	0.50
froth tailing	24.28	24.27	12.54	64.46
cell concentrate	74.95	75.08	86.77	35.04
Flotation % Recovery	**75.53**	**75.57**	**87.37**	**35.21**

Notes: (1) wet basis, (2) dry basis

Appendix A6 Removal of CaO and MgO from Reject Pebble

Data recorded by:	krg, ajh	Test Date:	9/28/98
		Print Date:	11/21/98
Test No.	8		

Water Usage	water (kg/h)
screen spray water	5116.57
flotation cell dilution	657.33
sparger trim water	294.67
froth launder water	317.33

Reagent Usage	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	6.80	49.45	54.90
pond water to conditioner	1.73	12.59	13.97
pond water to cell	2.47	17.98	19.96
total pond water	11.00	80.02	88.84
STPP	0.17	1.23	1.36
Collector	0.13	0.96	1.07
Frother	0.02	0.11	0.13

	Flow Rate (kg/h)			*Analyses*			
	slurry	liquid	solids	% Solids(1)	% P_2O_5 (2)	% Insol(2)	% MgO(2)
low grade pebble	288.95	151.49	137.46	47.57	26.48	12.79	1.32
screen feed	5462.25	5310.12	152.13	2.79	26.01	12.17	1.68
-400 mesh waste	5118.66	5116.57	2.09	0.04	22.63	12.79	3.40
deslimed pebble	343.59	193.56	150.04	43.67	26.06	12.16	1.65
rod mill discharge	350.39	200.35	150.04	42.82	26.06	12.16	1.65
conditioner discharge	352.12	202.08	150.04	42.61	26.06	12.16	1.65
froth tailing	484.56	458.34	26.22	5.41	23.56	5.11	4.70
cell concentrate	822.04	698.22	123.82	15.06	26.59	13.65	1.01

Column Cell (8 in. dia.)	
air - cm/sec	na
air % holdup	na
froth product - cm/sec	0.46
concentrate - cm/sec	0.73

Distributions	Weight %(2)	P_2O_5 %	Insol %	MgO %
low grade pebble	100.00	100.00	100.00	100.00
-400 mesh waste	1.38	1.20	1.45	2.79
froth tailing	17.23	15.61	7.24	48.25
cell concentrate	81.39	83.20	91.32	48.97
Flotation % Recovery	**82.53**	**84.20**	**92.66**	**50.37**

Notes: (1) slurry basis, (2) dry basis

Appendix A7 Removal of CaO and MgO from Reject Pebble

Data recorded by:	KRG,JAH,CW,	Test Date:	10/1/98	***Test No.***	9
		Print Date:	11/21/98		

Water Usage	water (kg/h)
screen spray water	2635.83
flotation cell dilution	745.73
sparger trim water	249.33
froth launder water	0.00

Reagent Usage	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	11.87	85.21	100.73
pond water to conditioner	2.10	15.09	17.84
pond water to cell	3.46	24.85	29.38
total pond water	17.43	125.16	147.95
STPP	0.16	1.12	1.32
Collector	0.13	0.95	1.12
Frother	0.02	0.12	0.14

	Flow Rate (kg/h)			***Analyses***			
	slurry	liquid	solids	% Solids(1)	% P_2O_5 (2)	% Insol(2)	% MgO(2)
low grade pebble	150.34	11.10	139.24	92.62	26.69	12.47	1.16
screen feed	2938.20	2795.91	142.29	4.84	26.48	13.24	1.20
-400 mesh waste	2638.01	2635.83	2.18	0.08	23.21	9.86	3.50
deslimed pebble	300.20	160.08	140.11	46.67	26.53	13.29	1.17
rod mill discharge	312.06	171.95	140.11	44.90	26.53	13.29	1.17
conditioner discharge	314.16	174.05	140.11	44.60	26.53	13.29	1.17
froth tailing	792.07	769.74	22.32	2.82	25.64	6.52	3.00
cell concentrate	520.62	402.83	117.79	22.63	26.70	14.57	0.82

Column Cell (8 in. dia.)	
air - cm/sec	0.26
air % holdup	84.56
froth product - cm/sec	0.76
concentrate - cm/sec	0.44

Distributions	Weight %(2)	P_2O_5 %	Insol %	MgO %
low grade pebble	100.00	100.00	100.00	100.00
-400 mesh waste	1.53	1.34	1.14	4.45
froth tailing	15.69	15.19	7.73	39.12
cell concentrate	82.78	83.47	91.13	56.43
Flotation % Recovery	**84.07**	**84.60**	**92.18**	**59.06**

Notes: (1) slurry basis, (2) dry basis

Appendix A8 Removal of CaO and MgO from Reject Pebble

Data recorded by:	KRG,JAH.CW	Test Date:	10/1/98	***Test No.***	***10***
		Print Date:	11/21/98		

Water Usage	
	water (kg/h)
screen spray water	2670.39
flotation cell dilution	745.73
sparger trim water	226.67
froth launder water	0.00

	Reagent Usage		
	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	11.74	84.71	98.14
pond water to conditioner	0.74	5.35	6.20
pond water to cell	2.16	15.60	18.08
total pond water	14.65	105.66	122.42
STPP	0.16	1.17	1.36
Collector	0.13	0.95	1.10
Frother	0.02	0.12	0.14

	Flow Rate (kg/h)			***Analyses***			
	slurry	liquid	solids	% Solids(1)	% P_2O_5 (2)	% Insol(2)	% MgO(2)
low grade pebble	150.40	11.78	138.62	92.17	26.47	12.54	1.30
screen feed	3045.54	2910.46	135.08	4.44	28.52	13.28	1.18
-400 mesh waste	2673.63	2670.39	3.24	0.12	24.81	14.84	1.80
deslimed pebble	371.91	240.07	131.84	35.45	28.61	13.24	1.16
rod mill discharge	383.65	251.81	131.84	34.36	28.61	13.24	1.16
conditioner discharge	384.39	252.55	131.84	34.30	28.61	13.24	1.16
froth tailing	592.73	580.54	12.19	2.06	24.04	6.09	4.25
cell concentrate	766.23	646.58	119.65	15.62	29.08	13.97	0.85

Column Cell (8 in. dia.)	
air - cm/sec	0.26
air % holdup	76.78
froth product - cm/sec	0.57
concentrate - cm/sec	0.67

	Distributions			
	Weight %(2)	P_2O_5 %	Insol %	MgO %
low grade pebble	100.00	100.00	100.00	100.00
-400 mesh waste	2.40	2.09	2.68	3.67
froth tailing	9.03	7.61	4.14	32.52
cell concentrate	88.57	90.30	93.18	63.82
Flotation % Recovery	**90.75**	**92.23**	**95.75**	**66.25**

Notes: (1) slurry basis, (2) dry basis

Appendix A9 Removal of CaO and MgO from Reject Pebble

Data recorded by:	KRG,JAH.CW	Test Date:	10/13/98
		Print Date:	11/21/98
Test No.	***11***		

Water Usage	water (kg/h)
screen spray water	2736.37
flotation cell dilution	634.67
sparger trim water	113.33
froth launder water	0.00

Reagent Usage	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	10.75	74.96	113.11
pond water to conditioner	1.24	8.62	13.00
pond water to cell	3.09	21.54	32.50
total pond water	15.08	105.12	158.61
STPP	0.15	1.06	1.60
Collector	0.27	1.88	2.84
Frother	0.02	0.11	0.16

	Flow Rate (kg/h)			***Analyses***			
	slurry	liquid	solids	% Solids[1]	% P_2O_5 [2]	% Insol[2]	% MgO[2]
low grade pebble	153.04	9.59	143.45	93.73	26.82	13.14	1.07
screen feed	2882.78	2778.94	103.84	3.60	26.74	12.90	1.23
-400 mesh waste	2739.19	2736.37	2.82	0.10	23.78	8.66	3.60
deslimed pebble	143.59	42.57	101.02	70.35	26.83	13.02	1.16
rod mill discharge	154.34	53.33	101.02	65.45	26.83	13.02	1.16
conditioner discharge	155.58	54.56	101.02	64.93	26.83	13.02	1.16
froth tailing	196.02	190.07	5.95	3.03	25.19	6.52	3.40
cell concentrate	710.65	615.58	95.07	13.38	26.93	13.43	1.02

Column Cell (8 in. dia.)	
air - cm/sec	0.26
air % holdup	69.78
froth product - cm/sec	0.19
concentrate - cm/sec	0.63

Distributions	Weight %[2]	P_2O_5 %	Insol %	MgO %
low grade pebble	100.00	100.00	100.00	100.00
-400 mesh waste	2.72	2.42	1.82	7.98
froth tailing	5.73	5.39	2.89	15.88
cell concentrate	91.56	92.19	95.28	76.15
Flotation % Recovery	**94.11**	**94.47**	**97.05**	**82.75**

Notes: (1) slurry basis, (2) dry basis

Appendix A10 Removal of CaO and MgO from Reject Pebble

Data recorded by:	KRG,JAH.CW	Test Date:	10/14/98	***Test No.***	***12***
		Print Date:	11/21/98		

Water Usage	
	water (kg/h)
screen spray water	2739.52
flotation cell dilution	634.67
sparger trim water	226.67
froth launder water	0.00

	Reagent Usage		
	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	10.01	69.55	83.71
pond water to conditioner	0.93	6.44	7.75
pond water to cell	0.32	2.23	2.69
total pond water	11.26	78.22	94.15
STPP	0.15	1.01	1.22
Collector	0.28	1.92	2.31
Frother	0.02	0.11	0.13

	Flow Rate (kg/h)			***Analyses***			
	slurry	liquid	solids	% Solids[(1)]	% P_2O_5 [(2)]	% Insol[(2)]	% MgO[(2)]
low grade pebble	154.27	10.32	143.95	93.31	26.71	12.62	1.03
screen feed	2930.85	2795.96	134.88	4.60	27.03	12.64	1.11
-400 mesh waste	2741.88	2739.52	2.36	0.09	23.86	9.04	3.40
deslimed pebble	188.97	56.44	132.52	70.13	27.09	12.70	1.07
rod mill discharge	198.98	66.46	132.52	66.60	27.09	12.70	1.07
conditioner discharge	199.90	67.38	132.52	66.29	27.09	12.70	1.07
froth tailing	333.45	320.52	12.93	3.88	26.17	5.98	3.10
cell concentrate	728.11	608.52	119.59	16.43	27.19	13.43	0.85

Column Cell (8 in. dia.)	
air - cm/sec	0.26
air % holdup	70.41
froth product - cm/sec	0.32
concentrate - cm/sec	0.64

	Distributions			
	Weight %[(2)]	P_2O_5 %	Insol %	MgO %
low grade pebble	100.00	100.00	100.00	100.00
-400 mesh waste	1.75	1.55	1.25	5.36
froth tailing	9.58	9.28	4.53	26.76
cell concentrate	88.66	89.18	94.21	67.88
Flotation % Recovery	**90.24**	**90.58**	**95.41**	**71.72**

Notes: (1) slurry basis, (2) dry basis

Appendix A11 Removal of CaO and MgO from Reject Pebble

Data recorded by:	KRG,JAH.CW	Test Date:	10/14/98	***Test No.*** ***13***
		Print Date:	11/21/98	

Water Usage	water (kg/h)
screen spray water	2783.62
flotation cell dilution	634.67
sparger trim water	226.67
froth launder water	0.00

Reagent Usage	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	10.07	91.44	105.62
pond water to conditioner	1.85	16.83	19.44
pond water to cell	3.34	30.29	34.99
total pond water	15.26	138.56	160.05
STPP	0.23	2.12	2.45
Collector	0.27	2.48	2.86
Frother	0.02	0.14	0.16

	Flow Rate (kg/h)			***Analyses***			
	slurry	liquid	solids	% Solids(1)	% P_2O_5 (2)	% Insol(2)	% MgO(2)
low grade pebble	146.48	36.31	110.17	75.21	26.92	12.18	0.99
screen feed	2965.10	2857.60	107.50	3.63	26.75	12.72	1.15
-400 mesh waste	2786.14	2783.62	2.52	0.09	23.27	9.30	3.40
deslimed pebble	178.95	73.97	104.98	58.66	26.83	12.80	1.09
rod mill discharge	189.02	84.04	104.98	55.54	26.83	12.80	1.09
conditioner discharge	190.88	85.90	104.98	55.00	26.83	12.80	1.09
froth tailing	316.67	307.07	9.60	3.03	24.88	6.72	3.30
cell concentrate	738.88	643.50	95.38	12.91	27.03	13.41	0.87

Column Cell (8 in. dia.)	
air - cm/sec	0.26
air % holdup	70.97
froth product - cm/sec	0.30
concentrate - cm/sec	0.66

Distributions	Weight %(2)	P_2O_5 %	Insol %	MgO %
low grade pebble	100.00	100.00	100.00	100.00
-400 mesh waste	2.34	2.04	1.71	6.95
froth tailing	8.93	8.31	4.72	25.72
cell concentrate	88.72	89.65	93.56	67.33
Flotation % Recovery	**90.85**	**91.52**	**95.20**	**72.36**

Notes: (1) slurry basis, (2) dry basis

Appendix A12 Removal of CaO and MgO from Reject Pebble

Data recorded by:	KRG,JAH.CW	Test Date:	10/21/98
		Print Date:	11/21/98
Test No.	14		

Water Usage	water (kg/h)
screen spray water	2759.53
flotation cell dilution	918.00
sparger trim water	0.00
froth launder water	0.00

Reagent Usage	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	9.89	66.52	74.66
pond water to conditioner	1.42	9.56	10.73
pond water to cell	3.96	26.61	29.86
total pond water	15.26	102.69	115.25
STPP	0.14	0.96	1.08
Collector	0.13	0.89	1.00
Frother	0.00	0.00	0.00

	Flow Rate (kg/h)			*Analyses*			
	slurry	liquid	solids	% Solids[1]	% P_2O_5 [2]	% Insol[2]	% MgO[2]
low grade pebble	166.60	17.95	148.65	89.22	27.02	13.15	1.02
screen feed	2965.36	2817.33	148.03	4.99	26.65	12.91	1.20
-400 mesh waste	2761.64	2759.53	2.11	0.08	23.06	9.00	4.21
deslimed pebble	203.72	57.80	145.92	71.63	26.70	12.97	1.16
rod mill discharge	213.60	67.69	145.92	68.31	26.70	12.97	1.16
conditioner discharge	215.03	69.11	145.92	67.86	26.70	12.97	1.16
froth tailing	399.17	385.70	13.47	3.37	24.16	5.98	4.10
cell concentrate	737.81	605.36	132.45	17.95	26.96	13.68	0.86

	Distributions				
		Weight %[2]	P_2O_5 %	Insol %	MgO %
Pebble not scrubbed	low grade pebble	100.00	100.00	100.00	100.00
	-400 mesh waste	1.43	1.24	1.00	5.00
Wemco Flotation Cell 2@1 ft3	froth tailing	9.10	8.25	4.21	31.02
	cell concentrate	89.47	90.51	94.79	63.98
	Flotation % Recovery	**90.77**	**91.65**	**95.74**	**67.35**

Notes: (1) slurry basis, (2) dry basis

Appendix A13 Removal of CaO and MgO from Reject Pebble

Data recorded by:	KRG,JAH.CW	Test Date:	11/3/98
		Print Date:	11/21/98
Test No.	15		

Water Usage

	water (kg/h)
screen spray water	2622.14
flotation cell dilution	884.00
sparger trim water	0.00
froth launder water	0.00

Reagent Usage

	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	5.93	39.58	49.68
pond water to conditioner	2.72	18.14	22.77
pond water to cell	3.58	23.92	30.02
total pond water	12.24	81.64	102.47
STPP	0.16	1.04	1.30
Collector	0.09	0.60	0.75
Frother	0.00	0.00	0.00

	Flow Rate (kg/h)			Analyses			
	slurry	liquid	solids	% Solids[1]	% P_2O_5 [2]	% Insol[2]	% MgO[2]
low grade pebble	159.29	9.41	149.88	94.09	26.66	12.80	1.31
screen feed	2879.59	2745.88	133.71	4.64	26.58	13.07	1.36
-400 mesh waste	2624.95	2622.14	2.81	0.11	22.89	9.03	3.93
deslimed pebble	254.64	123.74	130.90	51.41	26.65	13.16	1.30
rod mill discharge	260.57	129.67	130.90	50.23	26.65	13.16	1.30
conditioner discharge	263.29	132.39	130.90	49.72	26.65	13.16	1.30
froth tailing	428.25	416.77	11.48	2.68	22.13	6.00	6.12
cell concentrate	722.62	603.21	119.41	16.52	27.09	13.85	0.84

Pebble not scrubbed

Wemco Flotation Cell 2@1 ft3

Distributions

	Weight %[2]	P_2O_5 %	Insol %	MgO %
low grade pebble	100.00	100.00	100.00	100.00
-400 mesh waste	2.10	1.81	1.45	6.09
froth tailing	8.59	7.15	3.94	38.69
cell concentrate	89.31	91.04	94.61	55.22
Flotation % Recovery	**91.23**	**92.72**	**96.00**	**58.80**

Notes: (1) slurry basis, (2) dry basis

Appendix A14 Removal of CaO and MgO from Reject Pebble

Data recorded by:	KRG,JAH.	Test Date:	11/3/98	***Test No.*** ***16***
		Print Date:	11/21/98	

Water Usage	water (kg/h)
screen spray water	2658.76
flotation cell dilution	906.67
sparger trim water	0.00
froth launder water	0.00

Reagent Usage	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	6.18	42.65	48.32
pond water to conditioner	2.97	20.47	23.20
pond water to cell	3.71	25.59	28.99
total pond water	12.85	88.71	100.51
STPP	0.16	1.08	1.22
Collector	0.11	0.75	0.84
Frother	0.00	0.00	0.00

	Flow Rate (kg/h)			***Analyses***			
	slurry	liquid	solids	% Solids(1)	% P_2O_5 (2)	% Insol(2)	% MgO(2)
low grade pebble	154.58	9.68	144.90	93.74	26.76	13.05	1.13
screen feed	2917.15	2774.57	142.59	4.89	26.59	13.02	1.31
-400 mesh waste	2661.02	2658.76	2.26	0.08	22.84	8.76	4.01
deslimed pebble	256.13	115.80	140.33	54.79	26.65	13.09	1.27
rod mill discharge	262.31	121.98	140.33	53.50	26.65	13.09	1.27
conditioner discharge	265.28	124.95	140.33	52.90	26.65	13.09	1.27
froth tailing	473.53	461.09	12.44	2.63	22.67	6.30	5.74
cell concentrate	702.12	574.23	127.89	18.21	27.04	13.75	0.83

	Distributions			
	Weight %(2)	P_2O_5 %	Insol %	MgO %
low grade pebble	100.00	100.00	100.00	100.00
-400 mesh waste	1.59	1.36	1.07	4.86
froth tailing	8.73	7.44	4.22	38.27
cell concentrate	89.69	91.20	94.71	56.87
Flotation % Recovery	**91.13**	**92.46**	**95.73**	**59.78**

Pebble not scrubbed

Wemco Flotation Cell 2@1 ft3

Notes: (1) slurry basis, (2) dry basis

Appendix A15 Removal of CaO and MgO from Reject Pebble

Data recorded by:	KRG,JAH	Test Date:	11/3/98	***Test No.***	*17*
		Print Date:	11/21/98		

Water Usage	
	water (kg/h)
screen spray water	2662.98
flotation cell dilution	861.33
sparger trim water	0.00
froth launder water	0.00

	Reagent Usage		
	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	6.18	43.92	58.88
pond water to conditioner	2.60	18.45	24.73
pond water to cell	4.08	28.99	38.86
total pond water	12.85	91.36	122.48
STPP	0.16	1.11	1.48
Collector	0.14	0.98	1.31
Frother	0.00	0.00	0.00

	Flow Rate (kg/h)			***Analyses***			
	slurry	liquid	solids	% Solids (1)	% P_2O_5 (2)	% Insol (2)	% MgO (2)
low grade pebble	151.15	10.45	140.70	93.09	26.71	12.80	1.23
screen feed	3030.10	2906.47	123.63	4.08	26.55	12.82	1.37
-400 mesh waste	2665.52	2662.98	2.55	0.10	23.55	9.15	3.76
deslimed pebble	364.57	243.49	121.08	33.21	26.62	12.89	1.32
rod mill discharge	370.75	249.67	121.08	32.66	26.62	12.89	1.32
conditioner discharge	373.35	252.27	121.08	32.43	26.62	12.89	1.32
froth tailing	545.45	529.32	16.13	2.96	23.87	7.00	4.76
cell concentrate	693.31	588.36	104.95	15.14	27.04	13.80	0.79

		Distributions			
		Weight % (2)	P_2O_5 %	Insol %	MgO %
Pebble not scrubbed	low grade pebble	100.00	100.00	100.00	100.00
	-400 mesh waste	2.06	1.83	1.47	5.66
Wemco Flotation Cell 2@1 ft3	froth tailing	13.05	11.73	7.13	45.36
	cell concentrate	84.89	86.44	91.40	48.98
	Flotation % Recovery	**86.68**	**88.05**	**92.77**	**51.92**

Notes: (1) slurry basis, (2) dry basis

Appendix A16 Removal of CaO and MgO from Reject Pebble

Data recorded by:	KRG,JAH.	Test Date:	11/3/98
		Print Date:	11/21/98
		Test No.	***18***

Water Usage	water (kg/h)
screen spray water	2161.22
flotation cell dilution	793.33
sparger trim water	0.00
froth launder water	0.00

Reagent Usage	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	6.06	44.45	52.97
pond water to conditioner	2.60	19.05	22.70
pond water to cell	4.02	29.49	35.13
total pond water	12.67	92.99	110.81
STPP	0.16	1.14	1.36
Collector	0.14	1.01	1.21
Diesel	0.48	3.52	4.20

	Flow Rate (kg/h)			***Analyses***			
	slurry	liquid	solids	% Solids(1)	% P_2O_5 (2)	% Insol(2)	% MgO(2)
low grade pebble	146.56	10.32	136.24	92.96	26.93	13.30	1.35
screen feed	2323.29	2197.19	126.10	5.43	26.83	12.56	1.28
-400 mesh waste	2163.82	2161.22	2.59	0.12	25.03	7.10	3.59
deslimed pebble	159.48	35.97	123.51	77.45	26.87	12.68	1.24
rod mill discharge	165.53	42.03	123.51	74.61	26.87	12.68	1.24
conditioner discharge	168.13	44.62	123.51	73.46	26.87	12.68	1.24
froth tailing	237.75	228.58	9.17	3.86	21.42	4.20	6.66
cell concentrate	723.71	609.37	114.33	15.80	27.31	13.36	0.80

Pebble not scrubbed

Wemco Flotation Cell 2@1 ft3

Distributions	Weight %(2)	P_2O_5 %	Insol %	MgO %
low grade pebble	100.00	100.00	100.00	100.00
-400 mesh waste	2.06	1.92	1.16	5.75
froth tailing	7.27	5.81	2.43	37.74
cell concentrate	90.67	92.27	96.41	56.51
Flotation % Recovery	**92.57**	**94.08**	**97.54**	**59.96**

Notes: (1) slurry basis, (2) dry basis

Appendix A17 Removal of CaO and MgO from Reject Pebble

Data recorded by:	KRG,JAH.CW		Test Date:	11/5/98		*Test No.*	*19*
			Print Date:	11/21/98			

Water Usage	water (kg/h)
screen spray water	2745.12
flotation cell dilution	457.87
sparger trim water	0.00
froth launder water	0.00

Reagent Usage	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	5.19	33.17	38.98
pond water to conditioner	2.47	15.80	18.56
pond water to cell	2.84	18.17	21.35
total pond water	10.51	67.13	78.89
STPP	0.16	1.00	1.17
Collector	0.14	0.88	1.04
Diesel	0.48	3.07	3.60

	Flow Rate (kg/h)			*Analyses*			
	slurry	liquid	solids	% Solids[1]	% P_2O_5 [2]	% Insol[2]	% MgO[2]
low grade pebble	177.14	20.64	156.49	88.35	26.71	12.98	1.30
screen feed	3038.62	2884.18	154.43	5.08	26.57	13.19	1.32
-400 mesh waste	2759.67	2745.12	14.54	0.53	25.03	7.10	3.59
deslimed pebble	278.95	137.00	141.95	50.89	26.87	14.09	1.06
rod mill discharge	284.14	144.25	139.89	49.23	26.73	13.82	1.08
conditioner discharge	286.61	146.72	139.89	48.81	26.73	13.82	1.08
froth tailing	142.88	136.17	6.71	4.70	20.77	5.14	6.84
cell concentrate	604.44	471.26	133.17	22.03	27.03	14.26	0.79

		Distributions			
		Weight %[2]	P_2O_5 %	Insol %	MgO %
Pebble scrubbed @ 50 % solids	low grade pebble	100.00	100.00	100.00	100.00
	-400 mesh waste	9.42	8.87	5.07	25.68
Wemco Flotation Cell 2@1 ft3	froth tailing	4.35	3.40	1.69	22.59
	cell concentrate	86.23	87.73	93.24	51.74
	Flotation % Recovery	**95.20**	**96.27**	**98.21**	**69.61**

Notes: (1) slurry basis, (2) dry basis

Appendix A18 Removal of CaO and MgO from Reject Pebble

Data recorded by:	KRG,JAH.CW	Test Date:	11/9/98
		Print Date:	11/21/98
Test No.	*20*		

Water Usage

	water (kg/h)
screen spray water	1657.62
flotation cell dilution	419.33
sparger trim water	0.00
froth launder water	0.00

Reagent Usage

	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	4.70	37.79	48.49
pond water to conditioner	2.47	19.89	25.52
pond water to cell	2.60	20.88	26.80
total pond water	9.76	78.57	100.81
STPP	0.12	0.99	1.27
Collector	0.07	0.57	0.74
Diesel	0.21	1.69	2.17

	Flow Rate (kg/h)			***Analyses***			
	slurry	liquid	solids	% Solids(1)	% P_2O_5 (2)	% Insol(2)	% MgO(2)
low grade pebble	171.91	47.63	124.28	72.29	26.71	12.98	1.30
screen feed	1909.24	1797.15	112.09	5.87	26.69	12.67	1.32
-400 mesh waste	1668.29	1657.62	10.67	0.64	25.03	7.10	3.59
deslimed pebble	240.95	127.34	113.61	47.15	26.82	13.62	1.04
rod mill discharge	245.65	144.23	101.41	41.28	26.86	13.26	1.08
conditioner discharge	248.12	146.70	101.41	40.87	26.86	13.26	1.08
froth tailing	119.91	115.35	4.56	3.80	19.63	4.52	7.56
cell concentrate	550.14	453.28	96.86	17.61	27.20	13.67	0.78

Distributions

		Weight %(2)	P_2O_5 %	Insol %	MgO %
Pebble scrubbed @ 50 % solids	low grade pebble	100.00	100.00	100.00	100.00
	-400 mesh waste	9.52	8.93	5.34	25.84
Wemco Flotation Cell 2@1 ft3	froth tailing	4.07	2.99	1.45	23.23
	cell concentrate	86.41	88.08	93.21	50.94
	Flotation % Recovery	**95.51**	**96.72**	**98.47**	**68.68**

Notes: (1) slurry basis, (2) dry basis

Appendix A19 Removal of CaO and MgO from Reject Pebble

Data recorded by:	S.P. & C.W.	Test Date:	11/9/98		*Test No.*	*21*
		Print Date:	11/21/98			

Water Usage	
	water (kg/h)
screen spray water	1635.49
flotation cell dilution	442.00
sparger trim water	0.00
froth launder water	0.00

Reagent Usage	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	4.64	39.70	51.21
pond water to conditioner	2.22	19.06	24.58
pond water to cell	2.72	23.29	30.04
total pond water	9.58	82.05	105.83
STPP	0.12	1.06	1.36
Collector	0.08	0.72	0.93
Diesel	0.27	2.31	2.98

	Flow Rate (kg/h)			*Analyses*			
	slurry	liquid	solids	% Solids(1)	% P_2O_5 (2)	% Insol(2)	% MgO(2)
low grade pebble	129.10	12.35	116.75	90.43	26.71	12.98	1.30
screen feed	1871.60	1765.74	105.86	5.66	26.70	12.46	1.31
-400 mesh waste	1645.75	1635.49	10.26	0.62	25.03	7.10	3.59
deslimed pebble	225.85	119.37	106.48	47.15	27.20	12.93	1.11
rod mill discharge	230.49	134.88	95.60	41.48	26.88	13.04	1.07
conditioner discharge	232.71	137.11	95.60	41.08	26.88	13.04	1.07
froth tailing	121.55	116.46	5.09	4.19	20.28	4.62	6.90
cell concentrate	555.88	465.37	90.51	16.28	27.25	13.51	0.74

		Distributions			
		Weight %(2)	P_2O_5 %	Insol %	MgO %
Pebble scrubbed @ 50 % solids	low grade pebble	100.00	100.00	100.00	100.00
	-400 mesh waste	9.69	9.09	5.52	26.52
Wemco Flotation Cell 2@1 ft3	froth tailing	4.81	3.65	1.78	25.28
	cell concentrate	85.50	87.26	92.69	48.21
	Flotation % Recovery	**94.68**	**95.98**	**98.11**	**65.60**

Notes: (1) slurry basis, (2) dry basis

Appendix A20 Removal of CaO and MgO from Reject Pebble

Data recorded by:	S.P. & C.W.	Test Date:	11/9/98	***Test No.***	***22***
		Print Date:	11/21/98		

Water Usage

	water (kg/h)
screen spray water	1630.81
flotation cell dilution	442.00
sparger trim water	0.00
froth launder water	0.00

Reagent Usage

	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	4.70	32.19	46.78
pond water to conditioner	2.10	14.40	20.93
pond water to cell	2.97	20.33	29.55
total pond water	9.76	66.92	97.26
STPP	0.12	0.85	1.23
Collector	0.11	0.74	1.08
Diesel	0.43	2.96	4.30

	Flow Rate (kg/h)			***Analyses***			
	slurry	liquid	solids	% Solids[1]	% P_2O_5 [2]	% Insol[2]	% MgO[2]
low grade pebble	161.08	15.18	145.91	90.58	26.71	12.98	1.30
screen feed	1896.23	1773.64	122.59	6.46	26.54	12.46	1.42
-400 mesh waste	1642.50	1630.81	11.70	0.71	25.03	7.10	3.59
deslimed pebble	253.72	119.51	134.21	52.90	26.66	13.90	1.12
rod mill discharge	258.42	147.53	110.89	42.91	26.70	13.03	1.19
conditioner discharge	260.52	149.63	110.89	42.56	26.70	13.03	1.19
froth tailing	221.31	210.81	10.50	4.74	22.99	4.42	5.34
cell concentrate	484.18	383.79	100.39	20.73	27.09	13.93	0.76

Pebble scrubbed @ 50 % solids

Wemco Flotation Cell 2@1 ft3

Distributions

	Weight %[2]	P_2O_5 %	Insol %	MgO %
low grade pebble	100.00	100.00	100.00	100.00
-400 mesh waste	9.54	9.00	5.43	24.08
froth tailing	8.56	7.42	3.04	32.15
cell concentrate	81.90	83.59	91.53	43.77
Flotation % Recovery	**90.54**	**91.85**	**96.79**	**57.65**

Notes: (1) slurry basis, (2) dry basis

Appendix A21 Removal of CaO and MgO from Reject Pebble

Data recorded by:	KRG,JAH, &SH	Test Date:	11/18/98	**Test No.** 23
		Print Date:	11/21/98	

Water Usage	water (kg/h)
screen spray water	1843.01
flotation cell dilution	491.87
sparger trim water	0.00
froth launder water	0.00

Reagent Usage	liquid (kg/h)	kg/ton pebble	kg/ton conc.
pond water to mill	5.31	45.43	55.84
pond water to conditioner	2.22	19.02	23.37
pond water to cell	2.78	23.77	29.22
total pond water	10.32	88.22	108.42
STPP	0.12	1.03	1.26
Collector	0.08	0.72	0.88
Diesel	0.42	3.59	4.41

	Flow Rate (kg/h)			**Analyses**			
	slurry	liquid	solids	% Solids[1]	% P_2O_5 [2]	% Insol[2]	% MgO[2]
low grade pebble	129.27	12.28	116.99	90.50	26.71	12.98	1.30
screen feed	2038.33	1925.98	112.36	5.51	27.05	13.03	1.38
-400 mesh waste	1853.87	1843.01	10.86	0.59	25.03	7.10	3.59
deslimed pebble	184.46	78.33	106.12	57.53	27.11	12.79	1.17
rod mill discharge	189.77	88.28	101.49	53.48	27.27	13.66	1.14
conditioner discharge	192.00	90.50	101.49	52.86	27.27	13.66	1.14
froth tailing	156.70	150.39	6.31	4.02	21.50	5.28	7.20
cell concentrate	529.95	434.76	95.19	17.96	27.65	14.22	0.74

Mechanical Cell (Wemco 2@1x1)

Distributions	Weight %[2]	P_2O_5 %	Insol %	MgO %
low grade pebble	100.00	100.00	100.00	100.00
-400 mesh waste	9.67	8.95	5.27	25.18
froth tailing	5.61	4.46	2.27	29.32
cell concentrate	84.72	86.59	92.46	45.49
Flotation % Recovery		**95.10**	**97.60**	**60.80**

Notes: (1) analyses based on slurry, (2) analyses based on dry solids.

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APPENDIX B

EQUIPMENT LISTS FOR BASE CASE AND ALTERNATE CASE

CLIENT: FLORIDA INSTITUTE OF PHOSPHATE RESEARCH
PROJ.NO.: 28-P925-00
PROJ. NAME PHOSPHATE ROCK TREATMENT FOR WASTE REDUCTION - BASE CASE
LOCATION: CENTRAL FLORIDA
AREA:
EST.TYPE:
PURPOSE:

Acc't No.	DESCRIPTION	QTY.	Units
01-49	**PROCESS EQUIPMENT**		
01-011-2	PRODUCT PUMP 2727 gpm, 100 ft, 1.15 S.G. HORIZONTAL CENTRIFUGAL NI-HARD OR EQUAL 150 HP	2	EA
01-021-2	TAILS PUMP 1052 gpm, 100 ft, 1.03 S.G. HORIZONTAL CENTRIFUGAL NI-HARD OR EQUAL 60 HP	2	EA
01-031-3	THICKENER UNDERFLOW PUMP 259 gpm, 100 ft, 1.78 S.G. HORIZONTAL CENTRIFUGAL NI-HARD OR EQUAL 30 HP	3	EA
01-040	SUMP PUMP 100 gpm, 50 ft, 1.1 S.G. HORIZONTAL CENTRIFUGAL NI-HARD OR EQUAL 10 HP	1	EA
01-051-2	RECYCLE WATER PUMP 3172 gpm, 100 ft, 1.0 S.G. VERTICAL C.S. 150 HP	2	EA
01-060	DEPRESSANT TRANSFER PUMP 150 gpm, 50 ft, 1.0 S.G. HORIZONTAL CENTRIFUGAL C.S. 5 HP	1	EA
01-071-2	DEPRESSANT METERING PUMP 8 gpm, 50 ft, 1.0 S.G. DIAPHRAGM METERING PUMP 316 SS 0.5 HP	2	EA
01-080	COLLECTOR RECYCLE PUMP 500 gpm, 50 ft, 1.1 S.G. HORIZONTAL CENTRIFUGAL C.S. 10 HP	1	EA
01-091-2	COLLECTOR METERING PUMP 1 gpm, 50 ft, 1.1 S.G. DIAPHRAGM METERING PUMP 316 SS 0.25 HP	2	EA
01-100	DEFOAMER RECYCLE PUMP 500 gpm, 50 ft, 0.8 S.G. HORIZONTAL CENTRIFUGAL C.S. 10 HP	1	EA
01-111-2	DEFOAMER METERING PUMP 5 gpm, 50 ft, 0.8 S.G. DIAPHRAGM METERING PUMP 316 SS 0.25 HP	2	EA

CLIENT:	FLORIDA INSTITUTE OF PHOSPHATE RESEARCH
PROJ.NO.:	28-P925-00
PROJ. NAME	PHOSPHATE ROCK TREATMENT FOR WASTE REDUCTION - BASE CASE
LOCATION:	CENTRAL FLORIDA
AREA:	
EST.TYPE:	
PURPOSE:	

Acc't No.	DESCRIPTION	QTY.	Units
04-010	**PRODUCT THICKENER** 200 ft dia, 20 ft Deep, CONE BOTTOM DORRCO RAKE THICKENER C.S. 20 HP	1	EA
05-011-3	**CONDITIONER AGITATORS** 24 in dia x 64 in Long DECO C.S., URETHANE COATED 30 HP	3	EA
05-020	**DEPRESSANT MIX TANK AGITATOR** 30 in dia DOUBLE PROP 316L SS 3.0 HP	1	EA
05-030	**DEPRESSANT USE TANK AGITATOR** 30 in dia SINGLE PROP 316L SS 3.0 HP	1	EA
09-011-3	**CONDITIONER TANKS (Incl with 05-011-3)** 6 ft dia x 6 ft High, 3.25 MIN. VERTICAL CYLINDRICAL, FLAT BOTTOM C.S., URETHANE LINED	3	EA
09-020	**PRODUCT PUMP BOX** 10 ft dia x 10 ft High, 1.5 MIN. VERTICAL CYLINDRICAL, FLAT BOTTOM C.S.	1	EA
09-030	**TAILS PUMP BOX** 7 ft dia x 8 ft High, 1.5 MIN. VERTICAL CYLINDRICAL, FLAT BOTTOM C.S.	1	EA
09-040	**DEPRESSANT STORAGE SILO** 10 ft dia x 10 ft High VERTICAL CYLINDRICAL, CONE BOTTOM C.S.	1	EA
09-050	**DEPRESSANT MIX TANK** 12 ft dia x 12 ft High, 10,000 gal VERT. CYL. FLAT BOTTOM, COVERED C.S.	1	EA
09-060	**DEPRESSANT USE TANK** 16 ft dia x 16 ft High, 22,000 gal VERT. CYL, FLAT BOTTOM, COVERED C.S	1	EA
09-070	**COLLECTOR STORAGE / USE TANK** 16 ft dia x 16 ft High, 22,000 gal VERT. CYL. FLAT BOTTOM, COVERED C.S.	1	EA
09-080	**DEFOAMER STORAGE / USE TANK** 16 ft dia x 16 ft High, 22,000 GAL VERT. CYL, FLAT BOTTOM, COVERED C.S.	1	EA
30-010	**DEPRESSANT SCREW FEEDER** 9 in dia x 12 ft Long ENCLOSED TROUGH SCREW CONVEYOR C.S. 5 HP	1	EA

CLIENT:	FLORIDA INSTITUTE OF PHOSPHATE RESEARCH
PROJ.NO.:	28-P925-00
PROJ. NAME	PHOSPHATE ROCK TREATMENT FOR WASTE REDUCTION - BASE CASE
LOCATION:	CENTRAL FLORIDA
AREA:	
EST.TYPE:	
PURPOSE:	

Acc't No.	DESCRIPTION	QTY.	Units
36-010	**DEPRESSANT TRUCK UNLOADING SYSTEM**	1	EA
	10 tph		
	PNEUMATIC CONVEYOR PKG.		
	MANUFACTURER'S STANDARD		
	130 HP		
37-010	**FLOTATION MACHINE**	2	EA
	5 CELL BANK @ 100 ft^3 PER CELL		
	MECHANICAL CELL		
	C.S.		
	301 HP		
49-010	**COLLECTOR TANK HEATER**	1	EA
	MAINTAIN TANK @ 60 deg F OR HIGHER		
	IMMERSION HEATER		
	316 SS		
	5 KW		
		40	

CLIENT: FLORIDA INSTITUTE OF PHOSPHATE RESEARCH
PROJ.NO.: 28-P925-00
PROJ. NAME PHOSPHATE ROCK TREATMENT FOR WASTE REDUCTION - ALTERNATE CASE
LOCATION: CENTRAL FLORIDA
AREA:
EST.TYPE:
PURPOSE:

Acc't No.	DESCRIPTION	QTY.	Units
01-49	**PROCESS EQUIPMENT**		
01-011-2	**PRODUCT PUMP** 605 gpm, 100 ft, 1.15 S.G. HORIZONTAL CENTRIFUGAL NI-HARD OR EQUAL 50 HP	2	EA
01-021-2	**TAILS PUMP** 421 gpm, 100 ft, 1.04 S.G. HORIZONTAL CENTRIFUGAL NI-HARD OR EQUAL 40 HP	2	EA
01-031-3	**THICKENER UNDERFLOW PUMP** 115 gpm, 100 ft, 1.78 S.G. HORIZONTAL CENTRIFUGAL NI-HARD OR EQUAL 20 HP	3	EA
01-040	**SUMP PUMP** 100 gpm, 50 ft, 1.1 S.G. HORIZONTAL CENTRIFUGAL NI-HARD OR EQUAL 10 HP	1	EA
01-051-2	**MILL DISCHARGE PUMP** 125 gpm, 100 ft, 1.78 S.G. HORIZONTAL CENTRIFUGAL C.S. 40 HP	2	EA
01-061-2	**RECYCLE WATER PUMP** 864 gpm, 100 ft, 1.0 S.G. VERTICAL C.S. 50 HP	2	EA
01-070	**DEPRESSANT TRANSFER PUMP** 150 gpm, 50 ft, 1.1 S.G. HORIZONTAL CENTRIFUGAL C.S. 5 HP	1	EA
01-081-2	**DEPRESSANT METERING PUMP** 8 gpm, 50 ft, 1.0 S.G. DIAPHRAGM METERING PUMP 316 SS 0.5 HP	2	EA
01-090	**COLLECTOR RECYCLE PUMP** 500 gpm, 50 ft, 1.1 S.G. HORIZONTAL CENTRIFUGAL C.S. 10 HP	1	EA
01-101-2	**COLLECTOR METERING PUMP** 1 gpm, 50 ft, 1.1 S.G. DIAPHRAGM METERING PUMP 316 SS 0.25 HP	2	EA
01-110	**DEFOAMER RECYCLE PUMP** 500 gpm, 50 ft, 0.8 S.G. HORIZONTAL CENTRIFUGAL C.S. 10 HP	1	EA

CLIENT: FLORIDA INSTITUTE OF PHOSPHATE RESEARCH
PROJ.NO.: 28-P925-00
PROJ. NAME PHOSPHATE ROCK TREATMENT FOR WASTE REDUCTION - ALTERNATE CASE
LOCATION: CENTRAL FLORIDA
AREA:
EST.TYPE:
PURPOSE:

Acc't No.	DESCRIPTION	QTY.	Units
01-121-2	**DEFOAMER METERING PUMP** 5 gpm, 50 ft, 0.8 S.G. DIAPHRAGM METERING PUMP 316 SS 0.25 HP	2	EA
04-010	**PRODUCT THICKENER** 100 ft dia, 20 ft Deep, CONE BOTTOM DORRCO RAKE THICKENER C.S. 10 HP	1	EA
05-011-3	**CONDITIONER AGITATORS** 18 in dia x 48 in Long DECO C.S., URETHANE COATED 20 HP	3	EA
05-020	**DEPRESSANT MIX TANK AGITATOR** 30 in dia DOUBLE PROP 316L SS 3.0 HP	1	EA
05-030	**DEPRESSANT USE TANK AGITATOR** 30 in dia SINGLE PROP 316L SS 3.0 HP	1	EA
09-011-3	**CONDITIONER TANKS (incl with 05-011-3)** 3 ft dia x 4 ft High, 3.25 MIN. VERTICAL CYLINDRICAL, FLAT BOTTOM C.S., URETHANE LINED	3	EA
09-020	**PRODUCT PUMP BOX** 6 ft dia x 6 ft High, 1.2 MIN. VERTICAL CYLINDRICAL, FLAT BOTTOM C.S.	1	EA
09-030	**TAILS PUMP BOX** 5 ft dia x 6 ft High, 1.2 MIN. VERTICAL CYLINDRICAL, FLAT BOTTOM C.S.	1	EA
09-040	**MILL DISCHARGE PUMP BOX** 3 ft dia x 6 ft High, 1.4 MIN. VERTICAL CYLINDRICAL, FLAT BOTTOM C.S.	1	EA
09-050	**PEBBLE SURGE BIN** 10 ft dia x 17 ft High, 10 ft STRAIGHT SIDE VERTICAL CYLINDRICAL, CONE BOTTOM C.S.	1	EA
09-060	**DEPRESSANT STORAGE SILO** 10 ft dia x 10 ft High VERTICAL CYLINDRICAL, CONE BOTTOM C.S.	1	EA
09-070	**DEPRESSANT MIX TANK** 12 ft dia x 12 ft High, 10,000 gal VERT. CYL. FLAT BOTTOM, COVERED C.S.	1	EA
09-080	**DEPRESSANT USE TANK** 16 ft dia x 16 ft High, 22,000 gal VERT. CYL, FLAT BOTTOM, COVERED C.S.	1	EA

CLIENT: FLORIDA INSTITUTE OF PHOSPHATE RESEARCH
PROJ.NO.: 28-P925-00
PROJ. NAME PHOSPHATE ROCK TREATMENT FOR WASTE REDUCTION - ALTERNATE CASE
LOCATION: CENTRAL FLORIDA
AREA:
EST.TYPE:
PURPOSE:

Acc't No.	DESCRIPTION	QTY.	Units
09-090	**COLLECTOR STORAGE / USE TANK** 16 ft dia x 16 ft High, 22,000 gal VERT. CYL, FLAT BOTTOM, COVERED C.S.	1	EA
09-100	**DEFOAMER STORAGE / USE TANK** 16 ft dia x 16 ft High, 22,000 gal VERT. CYL, FLAT BOTTOM, COVERED C.S.	1	EA
27-010	**VERTIMILL** 47.3 tph, WI=12, F80=4000, P80=230 VERTICAL TOWER MILL MANUFACTURER'S STANDARD 350 HP	1	EA
29-010	**FLOTATION CONVEYOR** 60 tph, 217 ft Long, 45 ft LIFT 24" WIDE BELT CONVEYOR C.S., RUBBER BELT 25 HP	1	EA
29-020	**MILL FEED CONVEYOR** 60 tph, 217 ft LONG, 45 ft LIFT 24" WIDE BELT CONVEYOR C.S., RUBBER BELT 25 HP	1	EA
30-010	**DEPRESSANT SCREW FEEDER** 9 in dia x 12 ft Long ENCLOSED TROUGH SCREW CONVEYOR C.S. 5 HP	1	EA
33-010	**FEEDER** 60 tph SYNTRON MODEL MF-200, ELECTROMECHANICAL MANUFACTURER'S STANDARD 5 HP	1	EA
34-010	**BELT SCALE** 24 in Wide, 0-100 tph SCALE ELECTRONIC LOAD CELL MANUFACTURER'S STANDARD	1	EA
36-010	**DEPRESSANT TRUCK UNLOADING SYSTEM** 10 tph PNEUMATIC CONVEYOR PKG. MANUFACTURER'S STANDARD 130 HP	1	EA
37-010	**FLOTATION MACHINE** 4 CELL BANK @ 100 ft^3 PER CELL MECHANICAL CELL C.S. 120.5 HP	1	EA
39-010	**LOGWASHER** 52 tph PHOSPHATE LOGWASHER 36 in x 25 ft Long, SLOPED C.S., MANUFACTURER'S STANDARD 60 HP	1	EA
49-010	**COLLECTOR TANK HEATER** MAINTAIN TANK @ 60 DEG F OR HIGHER IMMERSION HEATER 316 SS 5 KW	1	EA
		49	

APPENDIX C

PHOSPHATE ROCK OPERATING COST ESTIMATE

Identification Code **STANDARD CASE**
Data File Dated: 11/31/1998

PRODUCTION DATA & RATES

Operating Schedule	7	Days per Week
Number of Draglin	1	Operating
Area Mined:	166	Acres per Year
Volume Stripped:	4.98	Million bcy/y
Ore Recovered:	5.36	Million bcy/y
Ore Density:	90	Dry pcf

Process Stream	Million Tons/Year	Million Tons x Miles
Rejects	0.083	0.021
Clays	1.627	1.627
Tailings	3.553	7.106
Pebble	0.249	0.000
Concentrate	0.996	0.000
Ore	6.508	13.017

Phosphate Rock Production Cost

	COST ELEMENT	$/PRODUCT TON
1	Electricity	3.15
2	Reagents	1.44
3	Severance Tax	1.57
4	Land Reclamation	0.60
5	Dam Building	0.65
6	Operating Labor	3.23
7	Contract Maintenance	0.80
8	Maintenance Labor	1.99
9	Maintenance Materials	2.00
10	Operating Supplies	0.48
11	Operating Services	0.57
12	Autos & Trucks	0.10
13	Insurance	0.12
14	Taxes	0.56
15	Mine Overhead	1.80
16	Other	0.04
17	**Subtotal Cost**	**19.10**
18	Depreciation	1.71
19	Depletion & Royalties	1.00
20	**Production Cost FOB Mine**	**21.81**

Identification Code **BASE CASE**
Data File Dated: 11/31/1998

PRODUCTION DATA & RATES

Operating Schedule	7	Days per Week
Number of Draglin	1	Operating
Area Mined:	133	Acres per Year
Volume Stripped:	4.00	Million bcy/y
Ore Recovered:	5.38	Million bcy/y
Ore Density:	90	Dry pcf

Process Stream	Million Tons/Year	Million Tons x Miles
Rejects	0.000	0.000
Clays	1.634	1.634
Tailings	3.569	7.138
Pebble	0.333	0.000
Concentrate	1.001	0.000
Ore	6.538	13.076

Phosphate Rock Production Cost

	COST ELEMENT	$/PRODUCT TON
1	Electricity	2.92
2	Reagents	1.35
3	Severance Tax	1.57
4	Land Reclamation	0.45
5	Dam Building	0.61
6	Operating Labor	3.01
7	Contract Maintenance	0.75
8	Maintenance Labor	1.86
9	Maintenance Materials	1.84
10	Operating Supplies	0.44
11	Operating Services	0.48
12	Autos & Trucks	0.10
13	Insurance	0.11
14	Taxes	0.52
15	Mine Overhead	1.68
16	Other	0.04
17	**Subtotal Cost**	**17.74**
18	Depreciation	1.60
19	Depletion & Royalties	1.00
20	**Production Cost FOB Mine**	**20.34**

Identification Code **ALTERNATE CASE**
Data File Dated: 11/31/1998

PRODUCTION DATA & RATES

Operating Schedule	7	Days per Week
Number of Draglin	1	Operating
Area Mined:	130	Acres per Year
Volume Stripped:	3.90	Million bcy/y
Ore Recovered:	5.25	Million bcy/y
Ore Density:	90	Dry pcf

Process Stream	Million Tons/Year	Million Tons x Miles
Rejects	0.000	0.000
Clays	1.594	1.594
Tailings	3.480	6.961
Pebble	0.325	0.000
Concentrate	0.976	0.000
Ore	6.376	12.751

Phosphate Rock Production Cost

	COST ELEMENT	$/PRODUCT TON
1	Electricity	2.92
2	Reagents	1.35
3	Severance Tax	1.57
4	Land Reclamation	0.45
5	Dam Building	0.61
6	Operating Labor	3.09
7	Contract Maintenance	0.77
8	Maintenance Labor	1.90
9	Maintenance Materials	1.84
10	Operating Supplies	0.44
11	Operating Services	0.48
12	Autos & Trucks	0.10
13	Insurance	0.12
14	Taxes	0.54
15	Mine Overhead	1.72
16	Other	0.04
17	**Subtotal Cost**	**17.94**
18	Depreciation	1.64
19	Depletion & Royalties	1.00
20	**Production Cost FOB Mine**	**20.58**

APPENDIX D

DAP PRODUCTION COST ESTIMATES

JACOBS ENGINEERING DAP COST MODEL
PHOSPHATE ROCK TREATMENT FOR WASTE REDUCTION

ELECTRICITY USED [KWH/T DAP]	112.000
FUEL USED [kg #2/T DAP]	7.619
COGENERATION UTILIZATION [decimal]	1.000
REAGENT COST [$/T DAP]	1.678
LABOR USED [mh/T DAP]	0.272
STEAM & OTHER COST [$/T DAP]	1.361
SUPPLIES & CONTRACTS [$/T DAP]	8.880
STORAGE & SHIPPING [$/T DAP]	2.204

ROCK SOURCE	FIPR	FIPR	FIPR
DAP PLANT	BARTOW	BARTOW	BARTOW
YEAR	STANDARD	BASE	ALTERNATE
ROCK COST [$/T] (FOB)	27.380	27.980	28.390
ROCK USED [T/T DAP]	1.804	1.796	1.812
SULFUR COST [$/T]	62.000	62.000	62.000
SULFUR USED [T/T DAP]	0.437	0.435	0.438
AMMONIA COST [$/T]	118.000	118.000	118.000
AMMONIA USED [T/T DAP]	0.225	0.225	0.225
LABOR RATE [$/MH]	20.000	20.000	20.000
LABOR INDEX [MH/MH FL]	1.000	1.000	1.000
CONSTRUCTED COST [Million$]	175.000	175.000	175.000
CONSTR. INDEX [$/$ FL]	0.990	0.990	0.990
ELECTRICITY COST [$/KWH]	0.038	0.038	0.038
FUEL COST [$/kg #2]	0.102	0.102	0.102
DAP FREIGHT [$/T DAP]	0.000	0.000	0.000
PLANT CAPACITY [Thousand TP	734.000	734.000	734.000
NORMAL SULFUR USE [T/T DAP]	0.438	0.438	0.438
ROCK	49.394	50.252	51.443
SULFUR	27.094	26.970	27.156
AMMONIA	26.550	26.550	26.550
RAW MATERIALS	103.038	103.772	105.149
ELECTRICITY	4.246	4.227	4.256
FUEL	0.775	0.772	0.777
REAGENTS	1.657	1.650	1.661
LABOR	5.428	5.403	5.440
PLANT OVERHEAD	7.681	7.611	7.717
SUPPLIES & CONTRACTS	8.771	8.731	8.791
TAXES & INSURANCE	0.873	0.869	0.875
STEAM & OTHER	1.358	1.352	1.361
COGEN & STEAM (CREDIT)	-7.727	-7.692	-7.745
STORAGE & SHIPPING	2.198	2.188	2.203
SGA	1.260	1.247	1.267
INTEREST ON WORKING CAPITAL	0.630	0.623	0.633
SUBTOTAL PROCESSING	27.151	26.981	27.237
COST OF CAPITAL	13.970	13.906	14.002
SUBTOTAL BOOK COST	13.970	13.906	14.002
TOTAL COST FOB PLANT	144.159	144.659	146.388
FREIGHT	0.000	0.000	0.000
TOTAL DELIVERED COST	144.159	144.659	146.388

FIPR - PHOSPHATE ROCK TREATMENT FOR WASTE REDUCTION 01/07/99
P.N. 28-P925-00
CENTRAL FLORIDA

PARAMETER	STANDARD	BASE	ALTERNATE	
RAW MATERIALS DATA :				
ROCK PERCENT CaO	42.750	42.780	42.690	
ROCK PERCENT SO3	1.400	1.390	1.410	
ROCK PERCENT P205	28.500	28.630	28.370	
ROCK PERCENT I&A	2.100	2.010	2.060	
ROCK PERCENT MgO	0.750	0.660	0.740	
ROCK CaF2 ? (1=Y,0=N)	0.000	0.000	0.000	
ROCK PERCENT F	3.700	3.700	3.700	
ROCK COST FOB MINE / SHORT TON	21.81	20.34	20.58	
ROCK TREATMENT COST / SHORT TO	0.00	5.14	2.25	
ROCK TRANSPORT COST / SHORT TO	2.50	2.50	2.50	
ROCK MER PENALTY / SHORT TON	3.07		3.06	
ROCK COST DELIVERED / SHORT TO	27.38	27.98	28.39	
SULFUR COST DEL. SHORT TON	62.00	62.00	62.00	
AMMONIA COST DEL. SHORT TON	118.00	118.00	118.00	
MANUFACTURING COSTS :				
LABOR RATE [$/MANHOUR]	17.40	17.40	17.40	
LABOR INDEX [MH/MH-FLORIDA]	1.000	1.000	1.000	
CONSTRUCTED COST [MM$]	168.00	168.00	168.00	
CONSTRUCTION INDEX [$/$ FLORID	0.990	0.990	0.990	
ELECTRICITY COST [$/KWH]	0.04	0.04	0.04	
FUEL COST [$/mm BTU]	3.07	3.07	3.07	
DAP MANUFACTURING CAPACITY [MTPY]	734	734	734	

01-06-1999

JACOBS ENGINEERING DAP COST MODEL
ROCK CALCULATOR
PHOSPHATE ROCK TREATMENT FOR WASTE REMOVAL

Rock Source : STANDARD ROCK

Input Data :

ROCK PERCENT CaO	42.750
ROCK PERCENT SO3	1.400
ROCK PERCENT P2O5	28.500
ROCK PERCENT I&A	2.100
ROCK PERCENT MgO	0.750
CaF2 IN ROCK (0 FOR NONE)	0.000
% F IN ROCK	3.700
CI LOSS	0.100
CS LOSS	3.400
PERCENT P2O5 RECOVERY	92.000
ACID PERCENT SO3	2.040
ACID PERCENT P2O5	28.000
I&A/P2O5 IN CLAR. OFLOW	0.065
PERCENT SOLIDS IN CLAR. UFLOW	15.000
% P2O5 AS 52% ACID	70.000
MAXIMUM MER OF DAP FEED	0.085

Rock Performance :

TONS OF ROCK PER TON OF DAP	1.804
TONS OF SULFUR PER TON OF DAP	0.437
MAXIMUM AVAILABLE % DAP	0.000

Plant Operating Parameters :

I&A/P2O5 RATIO	0.074
MgO/P2O5 RATIO	0.026
FILTER ACID MER	0.091
I&A in OVERFLOW	0.065
% to UNDERFLOW	0.385
% to OVERFLOW	0.615
OVERFLOW MER	0.091
UNDERFLOW P2O5	0.000

JACOBS ENGINEERING DAP COST MODEL
ROCK CALCULATOR
PHOSPHATE ROCK TREATMENT FOR WASTE REMOVAL

Rock Source : BASE CASE ROCK

Input Data :

ROCK PERCENT CaO	42.780
ROCK PERCENT SO3	1.390
ROCK PERCENT P2O5	28.630
ROCK PERCENT I&A	2.010
ROCK PERCENT MgO	0.660
CaF2 IN ROCK (0 FOR NONE)	0.000
% F IN ROCK	3.700
CI LOSS	0.100
CS LOSS	3.400
PERCENT P2O5 RECOVERY	92.000
ACID PERCENT SO3	2.040
ACID PERCENT P2O5	28.000
I&A/P2O5 IN CLAR. OFLOW	0.065
PERCENT SOLIDS IN CLAR. UFLOW	15.000
% P2O5 AS 52% ACID	70.000
MAXIMUM MER OF DAP FEED	0.085

Rock Performance :

TONS OF ROCK PER TON OF DAP	1.796
TONS OF SULFUR PER TON OF DAP	0.435
MAXIMUM AVAILABLE % DAP	100.000

Plant Operating Parameters :

I&A/P2O5 RATIO	0.070
MgO/P2O5 RATIO	0.023
FILTER ACID MER	0.085
I&A in OVERFLOW	0.062
% to UNDERFLOW	0.385
% to OVERFLOW	0.615
OVERFLOW MER	0.085
UNDERFLOW P2O5	0.000

01-06-1999

JACOBS ENGINEERING DAP COST MODEL
ROCK CALCULATOR
PHOSPHATE ROCK TREATMENT FOR WASTE REMOVAL

Rock Source : ALTERNATE ROCK

Input Data :

ROCK PERCENT CaO	42.690
ROCK PERCENT SO3	1.410
ROCK PERCENT P2O5	28.370
ROCK PERCENT I&A	2.060
ROCK PERCENT MgO	0.740
CaF2 IN ROCK (0 FOR NONE)	0.000
% F IN ROCK	3.700
CI LOSS	0.100
CS LOSS	3.400
PERCENT P2O5 RECOVERY	92.000
ACID PERCENT SO3	2.040
ACID PERCENT P2O5	28.000
I&A/P2O5 IN CLAR. OFLOW	0.065
PERCENT SOLIDS IN CLAR. UFLOW	15.000
% P2O5 AS 52% ACID	70.000
MAXIMUM MER OF DAP FEED	0.085

Rock Performance :

TONS OF ROCK PER TON OF DAP	1.812
TONS OF SULFUR PER TON OF DAP	0.438
MAXIMUM AVAILABLE % DAP	0.000

Plant Operating Parameters :

I&A/P2O5 RATIO	0.073
MgO/P2O5 RATIO	0.026
FILTER ACID MER	0.090
I&A in OVERFLOW	0.064
% to UNDERFLOW	0.385
% to OVERFLOW	0.615
OVERFLOW MER	0.090
UNDERFLOW P2O5	0.000