

ABSTRACT

POTASSIUM PHOSPHATES - PRODUCTS AND PROCESSES

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Pennzoil Company and Phosphate Engineering & Construction Company, Inc., (PECO) have made important technical developments to allow for the production of phosphoric acid from phosphate rock without flotation and the economical production of fertilizer grade potassium orthophosphates and potassium polyphosphates directly from wet process phosphoric acid and potash or directly from phosphate rock and potash.

The Drechsel process produces phosphoric acid from high silica phosphate ore without the usual flotation step. Excess phosphoric acid is used to produce a monocalcium phosphate/phosphoric acid solution which rejects the inert silica material. The monocalcium phosphate solution is then contacted with a stoichiometric quantity of sulfuric acid to produce gypsum and phosphoric acid. The gypsum is removed by filtration and the product phosphoric acid stream is split, part being recycled for the solution of the ore and the remainder becoming the net product stream. Elimination of the flotation step results in an estimated reduction of \$35-\$40 per ton in P_2O_5 production cost.

In the Pennzoil process, to produce potassium phosphates directly from rock and potash, potassium bisulfate is produced as an intermediate product. The bisulfate, along with sulfuric acid, acidulates the rock to produce a solution of monopotassium phosphates (MKP) in phosphoric acid. This solution is further processed to isolate fertilizer grade MKP.

PECO, in conjunction with Potash Corporation of Saskatchewan (PCS), has developed a very economical method of preparing MPK from wet process

phosphoric acid and potassium chloride. The MKP produced by this process is very pure with most impurities existing at part-per-million levels. Since conventional potash and wet process phosphoric acid are used as the raw materials, the cost of producing the MKP is less than half the cost of the conventional route.

Using MKP as a starting material, Pennzoil has developed processes to produce fertilizer grade and potassium polyphosphates which result in significantly lower freight, storage, handling and application costs.

The polyphosphates are highly water soluble and are, therefore, very useful in preparing fertilizer solutions. The 0-50-30 MKP would replace the conventional 10-34-0 as a base material for the preparation of liquid fertilizers. The 0-50-30 material has many more units of plant food per ton of product and has a storage life of many years, as compared to the 44 units of plant food contained in the 10-34-0 base solution which has a very short shelf life. Due to the high nutrient content of the 0-50-30 material, shipping and storing costs are significantly reduced.

The high purity MKP is an excellent base material upon which to build potassium pyrophosphate at a cost competitive with the sodium tripolyphosphate currently on the market.

INTRODUCTION

The purpose of this presentation is to describe the processes that the Pennzoil Company and Phosphate Engineering and Construction Company (PECO) have developed to produce potassium phosphate fertilizers, and wet phosphoric acid, and to describe relationships that exist between Pennzoil Company and PECO concerning these processes.

The Pennzoil processes involve the production of potassium phosphates from potassium bisulfate and phosphate rock, whereas the PECO processes involve the production of potassium phosphates from potassium chloride and wet acid. Also, Pennzoil Company has developed a process to produce wet phosphoric acid from high silica rock or flotation feed, and PECO has extended the process to handle matrix.

As you are probably aware, Pennzoil Company has gotten out of the minerals business, except for sulfur and petroleum, and has no intention of utilizing these phosphate technologies. And, since we believe that our technologies compliment the PECO technologies, we have granted an exclusive license to PECO to market our phosphate technologies.

I will discuss the products and the Pennzoil process, and Leif Bouffard of PECO will describe their processes and the overall economics of both of our technologies.

DESCRIPTION OF THE PRODUCTS

The Products

High analysis potassium phosphate products have substantial potential in the future fertilizer industry.

Table I lists the potassium orthophosphates and potassium polyphosphates which are suitable as fertilizer products that can be produced economically by the Pennzoil-PECO technologies.

Product Advantages

A number of properties of potassium phosphates result in these fertilizers being superior to currently available potassium and phosphate fertilizers, muriate of potash, and triple superphosphate.

Being chloride-free and low in fluoride content, potassium phosphates have a very low "salt index" compared to other fertilizer products. The salt index is a measure of the tendency of a fertilizer to burn crops. Also, semiarid areas of high irrigation benefit from low salt index fertilizer, as buildup of nonnutrient salts in the soil tend to inhibit crop growth. High cost potassium sulfate or potassium-magnesium sulphate, which has a low plant food analysis, is currently used as the source of potassium for these crops/areas.

Table 2 lists the salt index of some commonly used fertilizer materials and the potassium phosphates.

Being chloride-free, potassium phosphates can be blended directly with urea (46-0-0) in either granular or solution form to produce very economical N-P-K fertilizers.

Being highly water soluble, potassium phosphates can be used to produce high nutrient liquid fertilizers. Table 3 compares the water solubility of certain potassium phosphates and other fertilizer products.

Characteristics such as prilling/granulation/blending, hygroscopicity, hardness and compatibility are superior to most commercially available fertilizer materials.

Since the potassium phosphates are high analysis fertilizers, they offer freight, storage, handling, and application cost advantages over currently available fertilizers. For example, 100 units of 0-50-30 potassium phosphate fertilizer contains the same nutrient as 108 units of triple superphosphate (0-46-0), plus 50 units of potash (0-0-60), or 158 units total. Potential production of potassium polyphosphates (0-54-36) offers even greater cost advantages.

Several greenhouse trials were conducted at Texas A&M University to determine if fertilizer materials with different salt indexes affected plant growth differently. These trials showed an excellent correlation between salt index values, germination of seeds and root growth in the fertilizer zone. That is, germination and early root growth were considerably better for low salt index materials.

BRIEF OVERVIEW OF THE PROCESSES

Table 4 outlines the Pennzoil and PECO processes for producing the potassium orthophosphates and potassium polyphosphates. The processes are as follows:

The Pennzoil Processes

1. Bisulfate Process
 - a. Aqueous route to produce solid KHSO_4 .
 - b. Molten solution route to produce $\text{KHSO}_4\text{-H}_2\text{SO}_4$.
2. K-Phos process to produce 0-24-6 from KHSO_4 or K_2SO_4 .
3. Processing of 0-24-6
 - a. To produce 8-48-12 by ammoniation and granulation.
 - b. To produce 0-46-31 (MKP) and high grade phosphoric acid by methanolic precipitation.
4. Polymerization of 0-46-31 (MKP)
 - a. To produce 0-54-36 (K-Poly)
 - b. To produce tetrapotassium pyrophosphate.

The PECO Process

1. Production of MKP from KCl and wet acid.
2. Polymerization of MKP
 - a. To produce K-Poly
 - b. To produce tetrapotassium pyrophosphate.

DESCRIPTION OF THE POTASSIUM PHOSPHATE PROCESSES

The following is a description of the Pennzoil processes. The description of the PECO process will be given by Leif Bouffard following this presentation.

The K-Phos Process to Produce 8-48-12 from KHSO_4 and Rock

Existing wet phosphoric acid plants can be converted to produce potassium phosphate fertilizers by the addition of KHSO_4 or K_2SO_4 to the reaction media. Pennzoil Company converted a small wet acid plant using western U.S. rock to produce 94 tons per day of an 8-48-12 solid fertilizer, or 190 tons per day of a 0-24-6 solution. The plant was operated for about 12 months during 1973 and 1974. Rock conversion and P_2O_5 recoveries were comparable to a conventional wet acid plant. K_2O was added as chloride-free KHSO_4 which is produced as an aqueous solution followed by crystallization of very pure KHSO_4 . A co-product of the process was hydrochloric acid. Alternatively, the K_2O could be added as a solution of $\text{KHSO}_4\text{-H}_2\text{SO}_4$ which is produced by reacting one mole of KCl with two moles of H_2SO_4 at 120°C .

Chemistry of the Process

The chemistry of the process for producing the potassium phosphate (K-Phos) is given in Figure 1. KHSO_4 is prepared as a solid by crystallization from solution or is prepared as a solution of $\text{KHSO}_4\text{-H}_2\text{SO}_4$. Then the KHSO_4 , along with H_2SO_4 , is used to acidulate the rock under the same conditions as those to produce wet acid. About 70-75 percent of the fluoride in the rock is precipitated as K_2SiF_6 and ends up in the gypsum pond as an insoluble material. The remaining fluorine is in the liquid product, the fluoride concentration of which is less than 0.4 wt%. Essentially, none is released into the atmosphere. The liquid product has an analysis of 0-24-6 and has a molecular equivalency of three moles of KH_2PO_4 and four moles of H_3PO_4 . This liquid can be ammoniated and granulated by conventional processes to produce a high quality fertilizer having an analysis of 8-48-12.

Schematic Flow Diagrams

Figure 2 is a schematic flow diagram of the process to produce KHSO_4 in solution. The plant consisted essentially of two reactors, a vacuum crystallizer, a belt filter, and an HCl absorption system. One mole of KCl and one mole of H_2SO_4 were fed into Reactor 1 which overflows by gravity into Reactor 2. Pure KHSO_4 was crystallized in the vacuum crystallizer, filtered from the slurry, washed and either dried or fed directly to the acidulation plant. Alternatively, KHSO_4 can be ammoniated to produce a 9-0-31-21(S) fertilizer product.

Figure 3 is a simplified flow diagram of the process to produce the molten solution of $\text{KHSO}_4\text{-H}_2\text{SO}_4$. This method produces a chloride-free KHSO_4 in excess sulfuric acid. The chloride is evolved as essentially anhydrous HCl . The reaction mixture is reacted long enough at 230°F to drive out the free HCl and reduces the free chloride to an acceptable level for K-Phos production. The excess sulfuric acid also helps to drive the reaction to completion. The advantages of this method over the aqueous method are that anhydrous HCl is produced and that the crystallizer, filter and reslurry equipment can be eliminated since the reactor solution is fed directly into the K-Phos plant digestion system. This process for producing the KHSO_4 was not used in our semicommercial plant but was demonstrated by Goulding in their plant and by us in the laboratory.

The schematic flow diagram of the acidulation plant is shown in Figure 4. This plant is identical to a wet acid plant except that KHSO_4 or $\text{KHSO}_4\text{-H}_2\text{SO}_4$, or K_2SO_4 is fed into one of the front compartments of the plant.

The KHSO_4 at Hanford was fed wet directly from the filter to a tank and was dissolved by the strong wash solution from the gypsum filter. The $\text{KHSO}_4\text{-H}_2\text{SO}_4$ solution would be fed from the reactor directly into one of the front compartments. All other aspects of the plant were identical to a conventional wet acid plant.

Process Advantages

1. The technology provides a substantial measure of pollution control. It effectively eliminates fluoride contamination commonly associated with phosphoric manufacture. There is no detectable evolution of HF or SiF_4 from

the acidulation reactors. The fluoride that ends up in the gypsum pond is in the form of K_2SiF_6 which is very insoluble.

2. Existing wet phosphoric acid plants can be modified to produce K-Phos products.

3. Anhydrous, high purity HCl co-product represents the raw material of choice for manufacture of liquid chlorine via Kel-Chlor or oxychlorination of ethylene to produce ethylene dichloride monomer. Both outlets are large and independent of caustic soda.

PRODUCTION OF MKP BY METHANOLIC PRECIPITATION

The reaction between potassium bisulfate, phosphate rock and sulfuric acid produces gypsum and a mother liquor having a P_2O_5 and K_2O analysis of about 24 wt% and 6 wt%, respectively. This mole equivalency of H_3PO_4 to KH_2PO_4 in the mother liquor is about 1/1. Due to the phase equilibrium restraints of the system, KH_2PO_4 cannot be separated from the H_3PO_4 by crystallization. The stable solid phase at the composition of the mother liquor is the double salt, $KH_2PO_4 \cdot H_3PO_4$, rather than KH_2PO_4 .

The addition of water miscible solvent, such as methanol, to the concentrated mother liquor alters the phase equilibria of the system, thereby causing the crystallization of KH_2PO_4 . During the crystallization by methanol, essentially all of the impurities in the mother liquor are crystallized out along with the KH_2PO_4 . The resulting mother liquor is processed to produce relatively pure phosphoric acid which contains a small amount of KH_2PO_4 .

This methanolic precipitation step was tested batch-wise and continuously by Pennzoil in the laboratory and by Goulding personnel in Ireland in a semicommercial plant. A methanolic precipitation plant was designed to be installed in 1974 at our Hanford plant. It was not constructed for operation, because we decided to produce the 8-48-12 product which did not require separation of the KH_2PO_4 from the mother liquor.

The flow diagram for this process is shown in Figure 5. In this process, the 0-24-6 solution is first concentrated to a level of about 43 percent P_2O_5 . It is then mixed with a recycle stream of methanol and the KH_2PO_4 precipitate with about 20 percent of the P_2O_5 present as H_3PO_4 . This slurry is then filtered; the filtrate is primarily all H_3PO_4 , and the filter cake is composed of KH_2PO_4 and some of the double salt $KH_2PO_4 \cdot H_3PO_4$. The filtrate is passed to the alcohol still, where it is separated into 95 percent methyl alcohol and a rather pure phosphoric acid. This phosphoric acid is very low in all impurities, with the exception of about 2.7 percent of K_2O .

The filter cake, consisting of mostly KH_2PO_4 with some double salt, $\text{KH}_2\text{PO}_4\text{-H}_3\text{PO}_4$, is then transferred to the methyl alcohol stripper. In this stripper, the methyl alcohol is boiled off to the methyl alcohol still. The slurry from the methyl alcohol still is fed to the centrifuge, where the KH_2PO_4 is washed, the mother liquor removed and then fed to the drier.

The relatively pure phosphoric acid produced contains about 2.7 percent K_2O and 32 percent P_2O_5 and makes an excellent grade of super phosphoric acid for solution fertilizers. Technical grade phosphoric acid can be produced from this acid by removing the K_2O by ion exchange or solvent extraction.

Alternatively, the acid could be recycled to the K-Phos reactors or Drechsel Process to produce additional 0-24-6 filtrate. This latter variation would eliminate phosphoric acid as an end product by converting all of the phosphate to the solid potassium phosphate fertilizer.

POLYMERIZATION OF 0-46-31 (MKP)

MKP can be polymerized directly to produce a fertilizer product having an analysis of 0-54-36. To produce tetrapotassium pyrophosphate, one mole of KOH is added to one mole of MKP, and the mixture is heated to polymerize the potassium orthophosphate. The resulting product is $K_4P_2O_7 \cdot 3H_2O$ which has an analysis of about 0-51-34. Since it is very hygroscopic, it is sold as a concentrated solution.

In the polymerization process, granulation and polymerization takes place simultaneously. The feed to the unit is a saturated solution of the orthophosphates and potassium hydroxide, if used.

Figure 6 is a schematic diagram of the process.

DESCRIPTION OF THE DRECHSEL PHOSPHORIC ACID PROCESS

General

The Drechsel phosphoric acid technology was developed to resolve many of the problems associated with the current processes.

In the Drechsel process, shown in Figure 7, coarse, high silica, phosphate ore is acidulated with excess phosphoric acid to produce a monocalcium phosphate/phosphoric acid solution (monocal) and reject inert material. The monocal solution is then contacted with a stoichiometric quantity of sulfuric acid to produce gypsum and phosphoric acid. The gypsum is removed by filtration, and the product phosphoric acid stream is split, part being recycled for acidulation of the phosphate ore and the remainder becoming the net product stream.

Fluoride contamination is prevented by adding a sodium or potassium salt to the monocal solution and precipitating the fluoride as a sodium or potassium fluorosilicate. If fluorosilicate recovery is described, it is filtered from the monocal solution; otherwise, it remains in the solution and is rejected along with the gypsum after sulfuric acid addition. The recovered fluorosilicate can be sold directly or hydrolyzed in the presence of monocal solution to synthetic fluorospar.

In an alternate mode of operation, monocalcium phosphate (MCP) can be recovered from the monocal solution crystallization and filtration. In this mode of operation, monocal solution is produced as discussed above; fluorides are removed via precipitation as fluorosilicates, and a portion of the monocalcium phosphate is crystallized and recovered as MCP product. The remainder of the monocal solution partially depleted in monocalcium phosphate content, is then contacted with sulfuric acid to produce gypsum and recycle phosphoric acid.

Chemistry of the Process

The basic chemistry of the Drechsel process is shown in Figure 8. The main steps of the process are: acidulation, two-stage gypsum crystallization removal of product acid or monocal solution and fluoride removal.

Block Flow Diagram

Figure 9 is a simplified block flow diagram of the pilot plant which illustrates key features of the processing. Key features are: sequential acidulation of the rock, countercurrent acidulation of the rock with recycle acid and neutralizing of the excess sulfate in the recycle acid with the monocal solution.

Status of Development

Status of development and patent position of the Drechsel process are given in Table 5.

Summary of Advantages

The Drechsel process offers a number of distinct advantages over conventional phosphoric acid processes including:

1. A process based on flotation feed, eliminating flotation circuits and wet grinding.
2. A process that could substantially reduce the manufacturing cost of merchant grade acid and triple superphosphate.
3. A process that readily lends itself to both retrofit and new plant construction.
4. Advanced configurations of the Drechsel process would include:
 - a. Fluoride removal and hydrolysis, allowing significant reduction in sulfur consumption.
 - b. Production of monocalcium phosphate (MCP) and the possibility of high analysis potassium phosphate fertilizers derived from MCP.
 - c. Use of matrix feed.
 - d. Major environmental advantages and associated by-product sales.
5. Elimination of the flotation step results in an estimated reduction of \$35-40 per ton in P_2O_5 production cost.

THE PCS/PECO PROCESS

As reported to you last year at this same meeting, Phosphate Engineering and Construction Company, Inc. (PECO) has developed, under the sponsorship of Potash Corporation of Saskatchewan (PCS), a process for the economical production of monopotassium phosphate (MKP) from wet process phosphoric acid and conventional potassium chloride. This is a significant breakthrough in the production of potassium phosphate since this material is now produced from furnace grade phosphoric acid and potassium hydroxide at considerably more cost. Using the PCS/PECO process, it is possible to produce a 0-50-30 MKP when purchasing phosphoric acid at \$2.60 per unit and potassium chloride at \$80 per ton for a total production cost of \$255 per ton of MKP. The analysis of the product produced by this process is generally of high purity.

The MKP process has been successfully operated on the bench and has been produced in a pilot plant of 100 pounds per day capacity at the PCS research facility in Saskatoon, Saskatchewan. The analysis of the MKP produced is shown on Figure 10. Based on the four to six months operation of the pilot plant, this process is now ready for demonstration in a demonstration plant with a capacity of thirty thousand tons per year.

At the current time, MKP is not sold in sufficient quantities on the open market to establish its sales price. Calculations were performed to predict what the actual value of the MKP is on the open market.

The primary market for the MKP is in the use of this material to prepare clear liquid fertilizers. It, therefore, would compete with the conventional 10-34-0 base material currently being used for the preparation of these clear liquid fertilizers. Two formulations which are now being produced using 10-34-0 as a base material are 4-12-24 and 3-10-20. Assuming that the price of these clear liquid fertilizers would be the same when prepared using MKP or 10-34-0, the value of the MKP is

calculated to be between \$375 to \$380 per short ton when competing with 10-34-0 materials.

It is possible to prepare various suspension formulations which do not require 10-34-0, utilizing materials such as MAP as a source of phosphate. When this is done, the MKP loses some of its advantage. When competing directly with MAP, its value then ranges from \$272 to \$290 per ton.

Now that a pure MKP material is economically available to use as a starting point, it is possible, using the Pennzoil phosphate technology, to convert this material into a potassium pyrophosphate tetrabasic material for use in the detergent industry. Currently, this material sells for \$1,200 to \$1,400 per ton.

PECO has been successful in producing this K-Pyro material, using the MKP material as a base, for a total production cost of \$452 per ton. Considering that the product is currently selling for over \$1,200 per ton, it is easily seen that this is a very profitable venture.

The market potential for the potassium pyrophosphate in the United States is approximately 20,000 tons per year. This is a small market, however, most detergent manufacturers would like to replace the sodium tripolyphosphate with potassium pyrophosphate since it is more desirable. The high price of the K-Pyro material now keeps this material out of their formulations. The market for the sodium tripolyphosphate is in the range of 600 to 700 thousand tons per year. The sodium triphosphate normally is sold at a price of \$750 per ton.

Proctor & Gamble has indicated that they intend to increase their usage of K-Pyro from 8,000 tons in 1988 to 16,000 tons in 1989. They have also indicated that K-Pyro would displace sodium tripolyphosphate, if the price for the two materials were the same.

Capital cost for a facility to produce 100,000 tons per year of K-Pyro is estimated to be 8.25 million U.S. dollars. This assumes a B/L installation near an existing phosphoric acid plant and does not include storage of raw materials or product.

Should all the 1,000 tons of K-Pyro be sold only as a replacement for the sodium tripolyphosphate at \$750 per ton, a net profit of 29.8 million U.S. dollars per year would result, with a payout time of less than four (4) months. Any sale into the K-Pyro market, at \$1,400 per tone would decrease this payout time.

The capital cost estimate was determined by factoring the original MKP capital operating cost estimate prepared for PCS by PECO. Throughout the preparation of the capital cost estimate, a conservative approach was used to arrive at the final capital cost.

This same conservative approach was used in arriving at the operating cost estimate. The quantity of phosphoric acid required per tone of K-Pyro includes a 10% loss of P2O5. Potash is used at 93% recovery, and the caustic potash is given as 100% effective usage because there is little or no way that this material could be lost in the operation.

It should also be noted that when the K-Pyro phosphate moves into the sodium tripolyphosphate market it is displacing sodium and not a potassium product, which increases the sale of potassium to the world market at the expense of the sale of sodium. This effectively improves and increases the overall potassium market.

PECO, having world wide exclusive licence to PCS MKP technology and Pennzoil potassium and phosphate technology, tools the future of potassium and phosphate are bright and look forward to that future.

TABLE 1

POTASSIUM PHOSPHATE PRODUCTS

Product	Formula	Analysis N-P ₂ O ₅ -K ₂ O	Total Plant Food
Monopotassium Phosphate	KH ₂ PO ₄	0-52-35	87
K-Phos®	KH ₂ PO ₄ •H ₃ PO ₄	8-48-12	68
K-Poly®	K(KPO ₃) _x OK	0-54-36	90
Tetrapotassium Pyrophosphate	K ₄ P ₂ O ₇	0-57-41	98

TABLE 2
SALT INDEX FACTORS OF FERTILIZER MATERIALS

Fertilizer Material	Salt Index	Total Plant Food	Adjusted Salt Index ¹
Monocalcium Phosphate*	19.0	56	33.9
Potassium Sulfate*	46.0	50.5	91.1
Potassium Chloride*	116.3	60.0	193.8
Monocalcium Phosphate*	19.0	56	33.9
Dipotassium Phosphate*	28.0	95	29.5
TVA Ammonium Polyphosphate	30.5	77	39.6
Monopotassium Phosphate*	27.0	86	31.4
Pennzoil 9-48-16	31.0	73	42.5
Pennzoil 0-50-40	11.5	90	12.8
Tetrapotassium Pyrophosphate*	25.5	100	25.5

*Reagent grade chemicals

¹Adjusted Salt Index = $\frac{\text{Salt Index} \times 100}{\text{Total Plant Food}}$

Reference: Jerry Allen Freeouf, Texas A&M, M.S. Thesis, 1975, Major Professor - L. R. Hosnere

TABLE 3
WATER SOLUBILITY OF CERTAIN POTASSIUM PRODUCTS

Product	Water Solubility (25°C)¹ Parts/100 part of Water
Monopotassium Phosphate	33.0
K-Poly®	
Tetrapotassium Phosphate	
Potassium Chloride	22.5
Potassium Sulfate	12.0

¹Lange's Handbook of Chemistry, 11th Ed., 1973.

TABLE 4

OUTLINE OF THE PENNZOIL AND PECO PROCESSES

The Pennzoil Processes

1. Bisulfate Process
 - A. Aqueous route to product solid KHSO_4
 - B. Molten solution route to produce $\text{KHSO}_4\text{-H}_2\text{SO}_4$
2. K-Phos® process to produce 0-24-6 from KHSO_4 of K_2SO_4
3. Process of 0-24-6
 - A. To produce 8-48-12 by ammoniation and granulation
 - B. To produce 0-46-31 (MKP) and high grade phosphoric acid by methanolic precipitation
4. Polymerization of 0-46-31 (MKP)
 - A. To produce 0-54-36 (K-Poly®)
 - B. To produce tetrapotassium pyrophosphate

The PECO Process

1. Production of MKP from KCl and wet acid
2. Polymerization of MKP
 - A. To produce K-Poly
 - B. To produce tetrapotassium pyrophosphate

TABLE 5

OUR ASSESSMENT OF THE DRECHSEL PROCESS

1. Patent Position

To Produce Wet Acid: U.S. 4,393,030 (7-12-83)
U.S. 4,392,032 (7-12-83)
U.S. 4,086,322 (4-25-78)
U.S. 4,160,657 (7-10-79)
U.S. 4,222,990 (9-16-80)
U.S. 4,435,370 (4-6-84)

To Produce Monocal for the K-Phos® Process: Same

To Process Rock Sources Not Processible by Conventional Technology:
Same

2. Program Status

To Produce Wet Acid: Demonstrated in pilot plant, 25 pounds of rock per hour; process needs to be demonstrated in prototype plant.

To Produce Monocal for the K-Phos® Process: Processing steps to remove fluoride and crystallize monocal have been carried out in lab; pilot plant and/or prototype plant is needed.

To Process Rock Sources Not Processible by Conventional Technology:
Each rock to be evaluated in pilot plant or prototype plant.

3. Technical Advantages

To Produce Wet Acid: Existing wet acid plants can be retrofitted; lower cost process due to lower feed rock cost and potential 10% savings in sulfuric acid; process can handle high silica coarse rock; no sulfur in product.

To Produce Monocal for the K-Phos® Process: Same advantages as for producing wet acid; advantages for the K-Phos® process - K_2O .

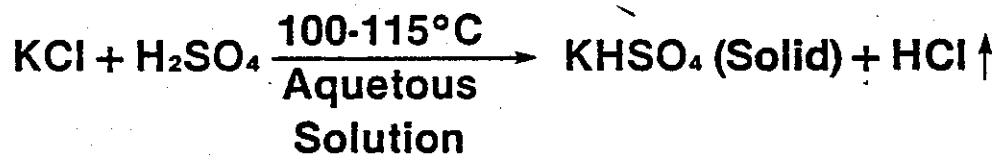
To Process Rock Sources Not Processible by Conventional Technology:
Same advantages as for producing wet acid.

FIGURE 1

CHEMISTRY OF THE PROCESS

PREPARATION OF POTASSIUM BISULFATE

1. Solid Product



2. KHSO₄ – H₂SO₄ Slurry



ROCK ACIDULATION

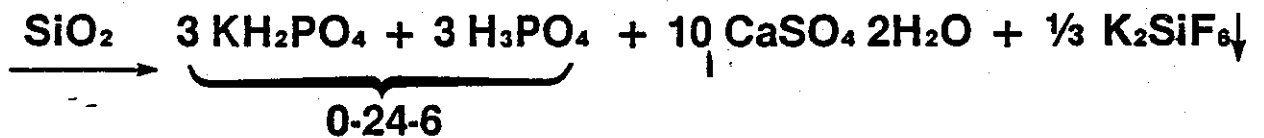


FIGURE 2
Preparation of Potassium Bisulfate (solid)

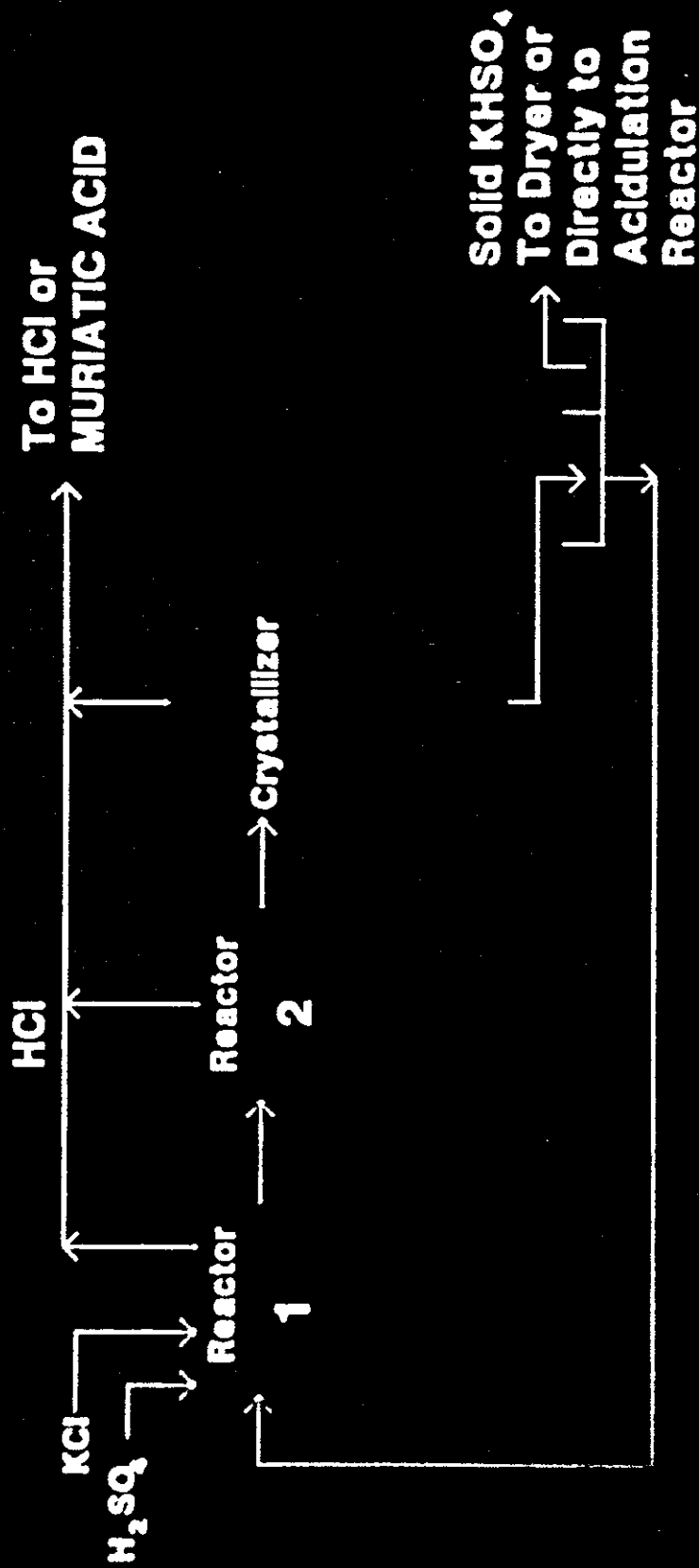


FIGURE 3
Preparation of Potassium Bisulfate -
Sulfuric Acid Solution

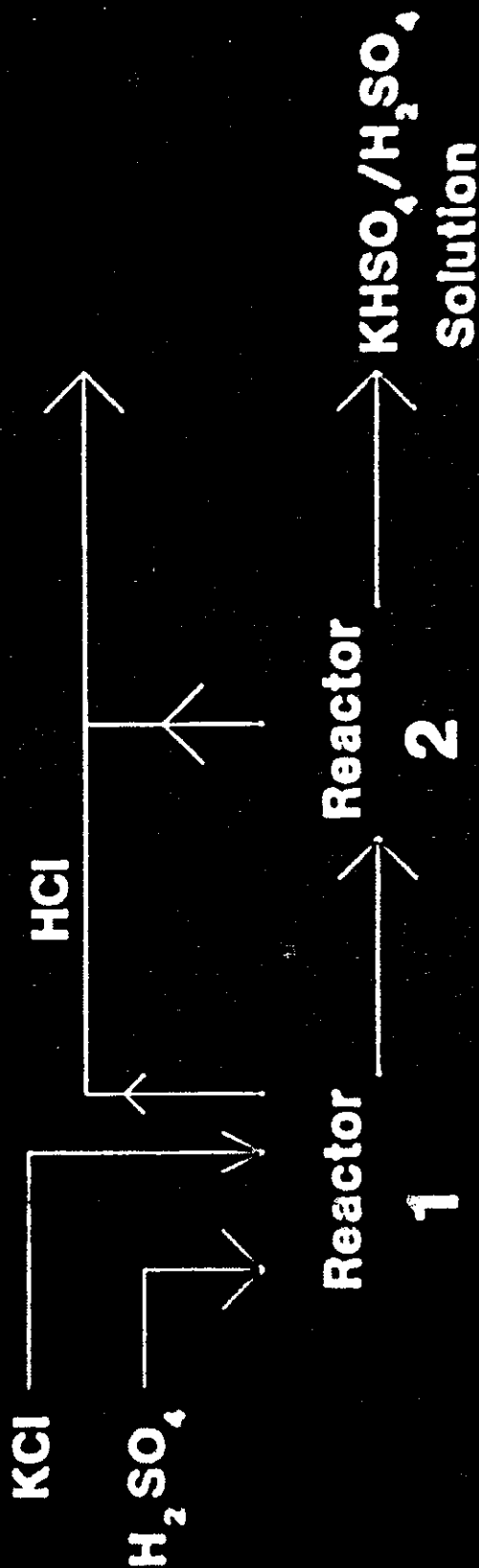


FIGURE 4
K-Phos Acidulation Plant

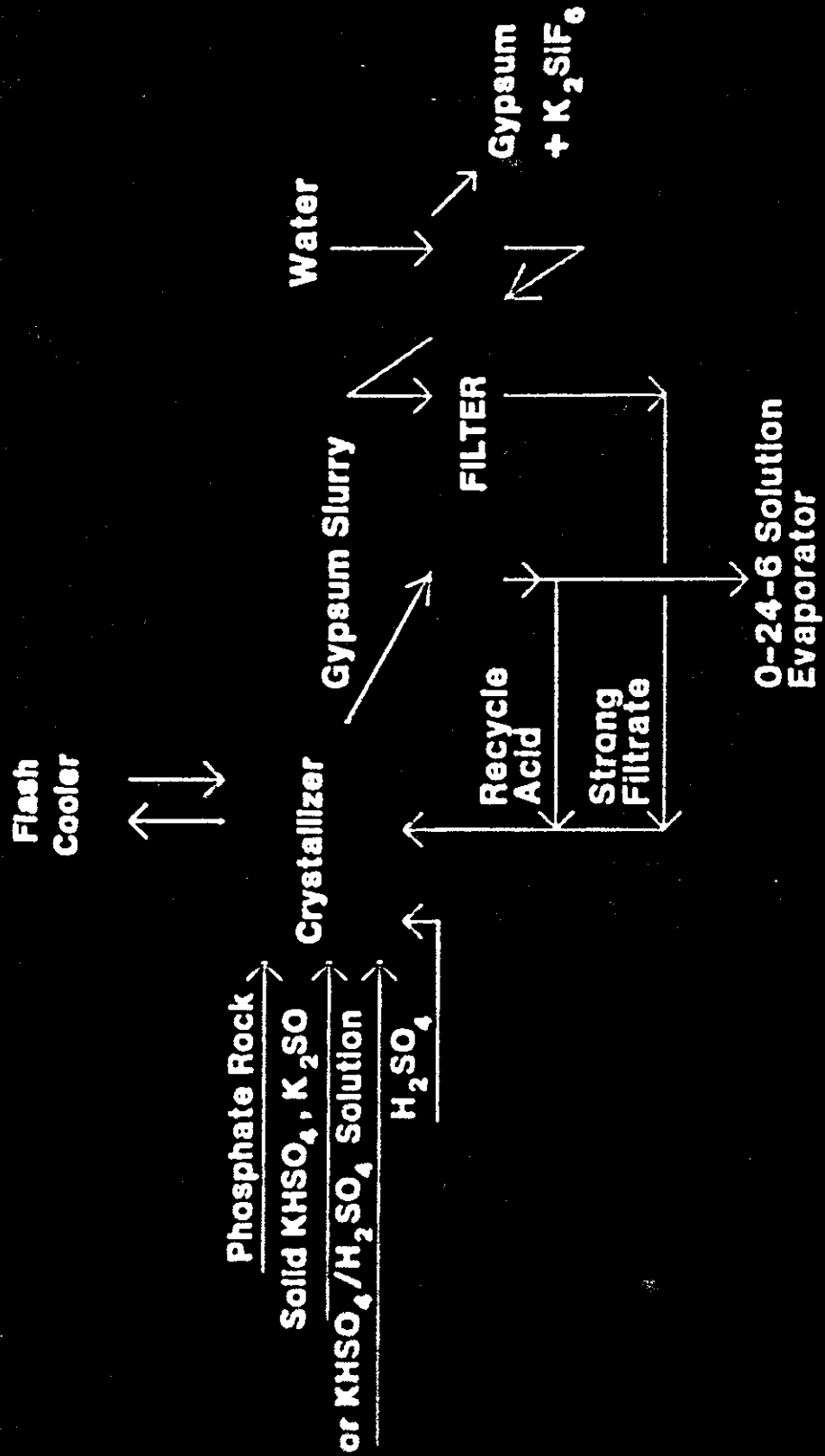


FIGURE 5

Methanolic Precipitation of KH_2PO_4

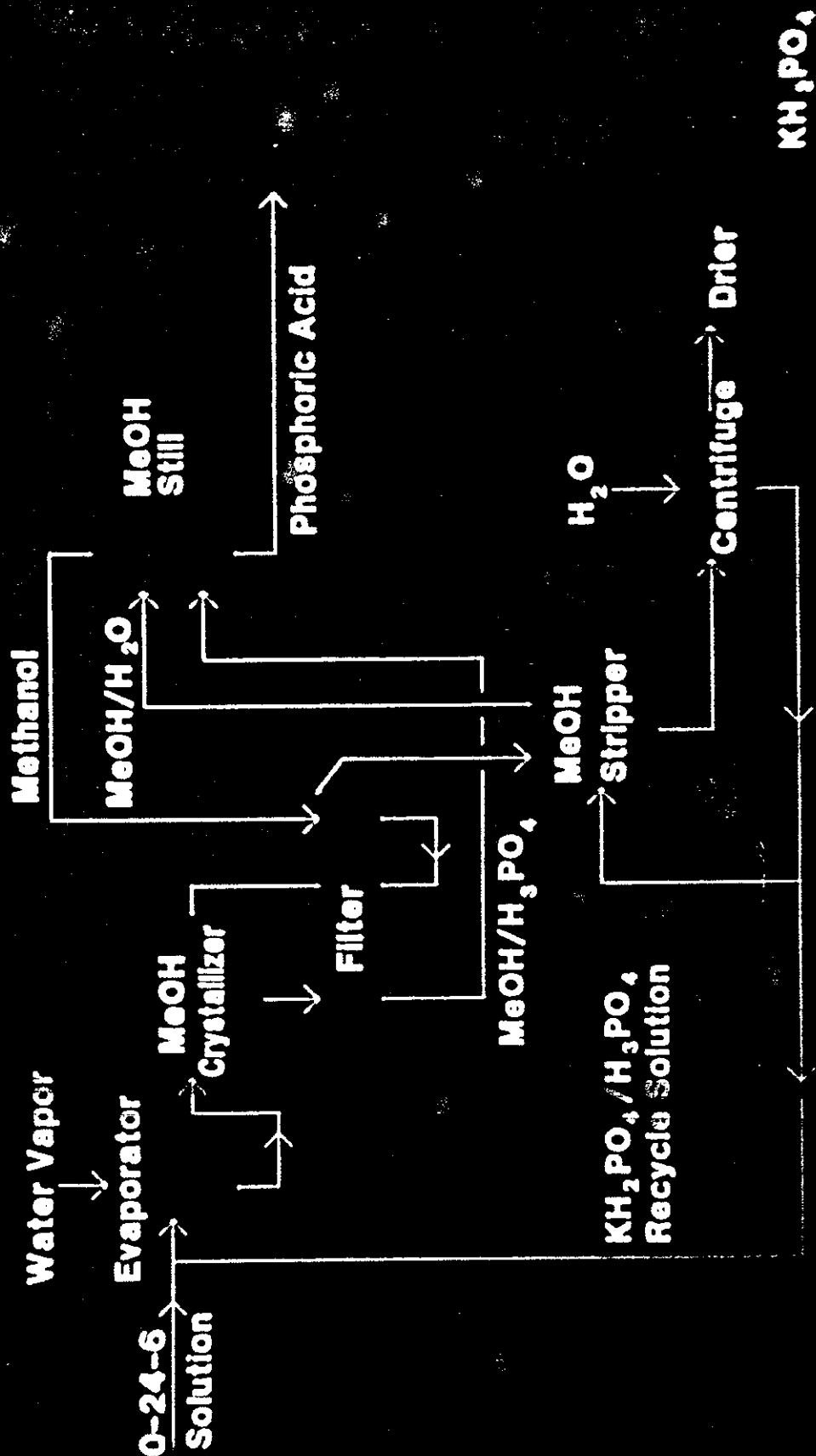


FIGURE 6

SCHMATIC DIAGRAM OF POLYMERIZATION REACTOR

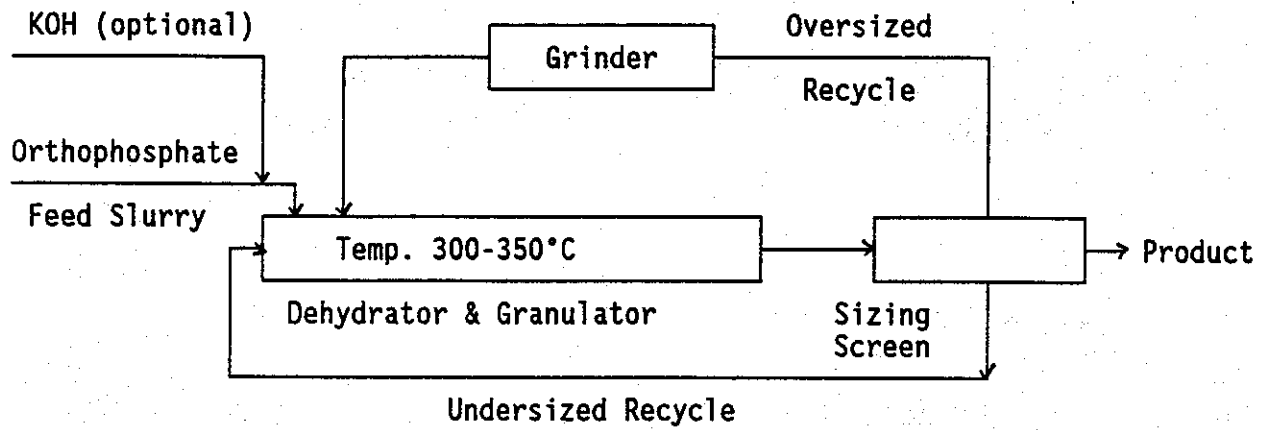


FIGURE 7

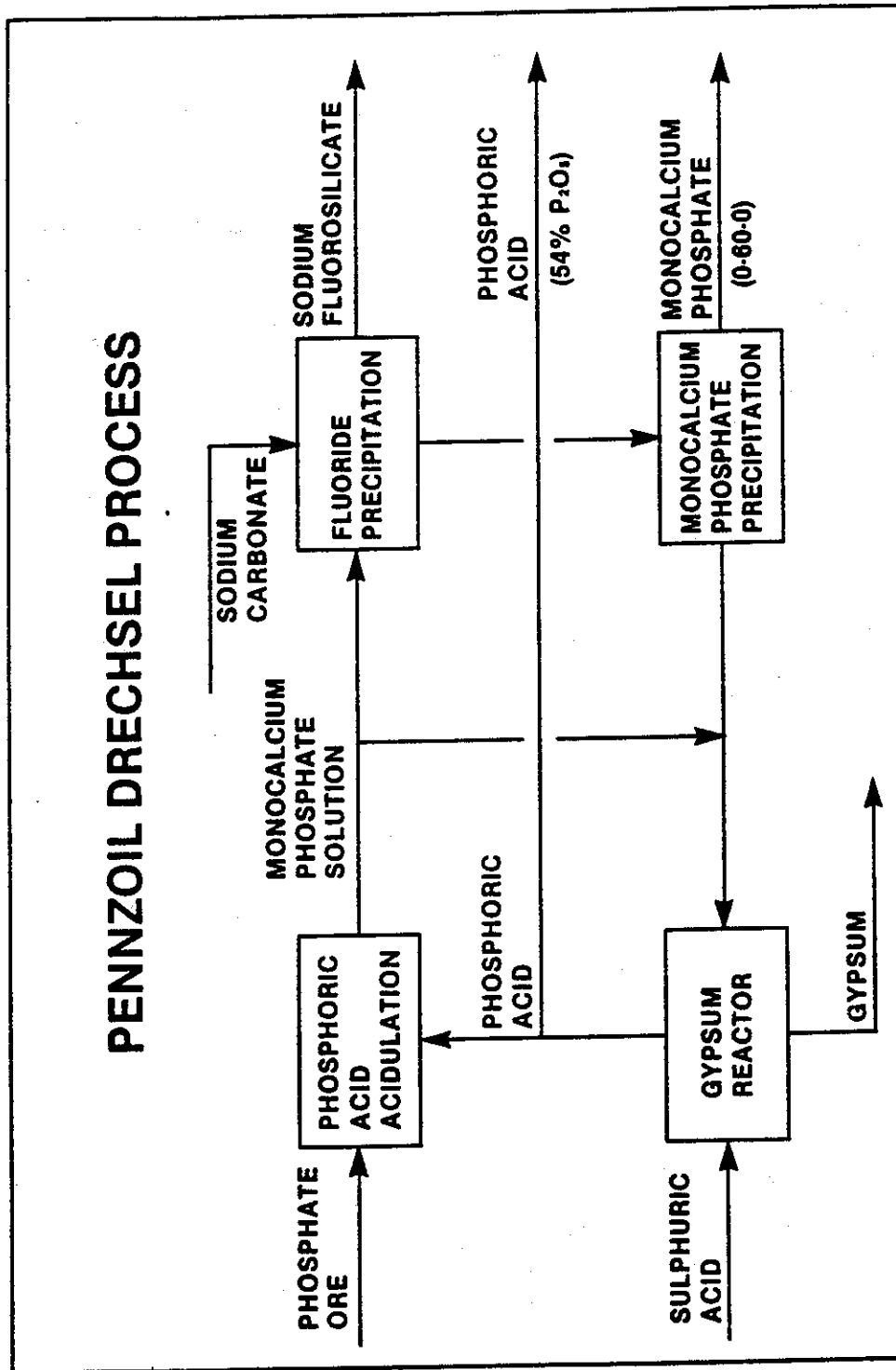
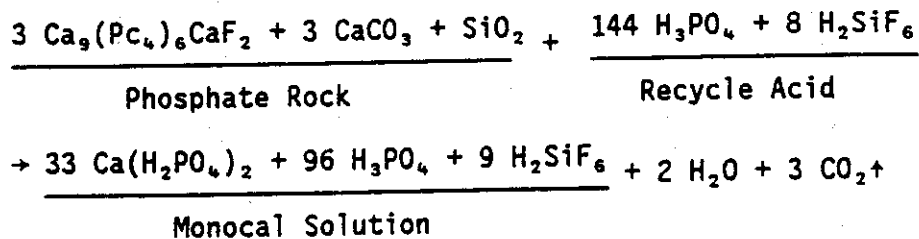


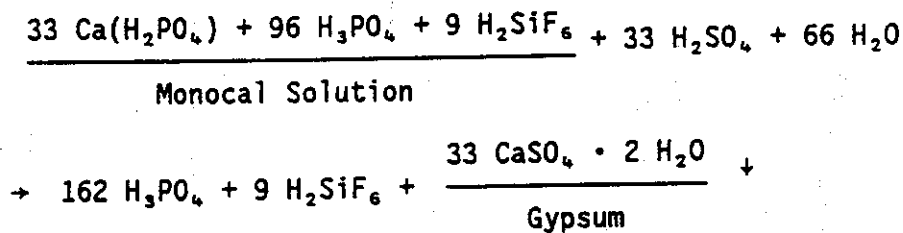
FIGURE 8

CHEMISTRY OF DRECHSEL PROCESS

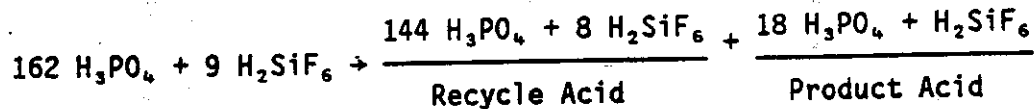
1. ACIDULATION



2. Two-stage Gypsum Crystallization



3. Removal of Product Acid



4. Fluoride Removal

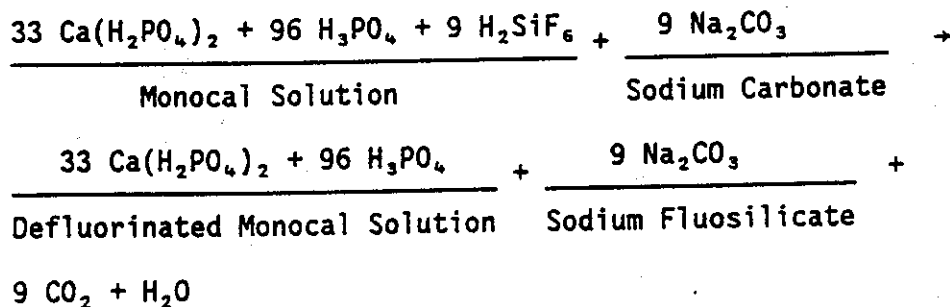


FIGURE 9

FIGURE 11
Drechsel Process - Pilot Plant Run 15

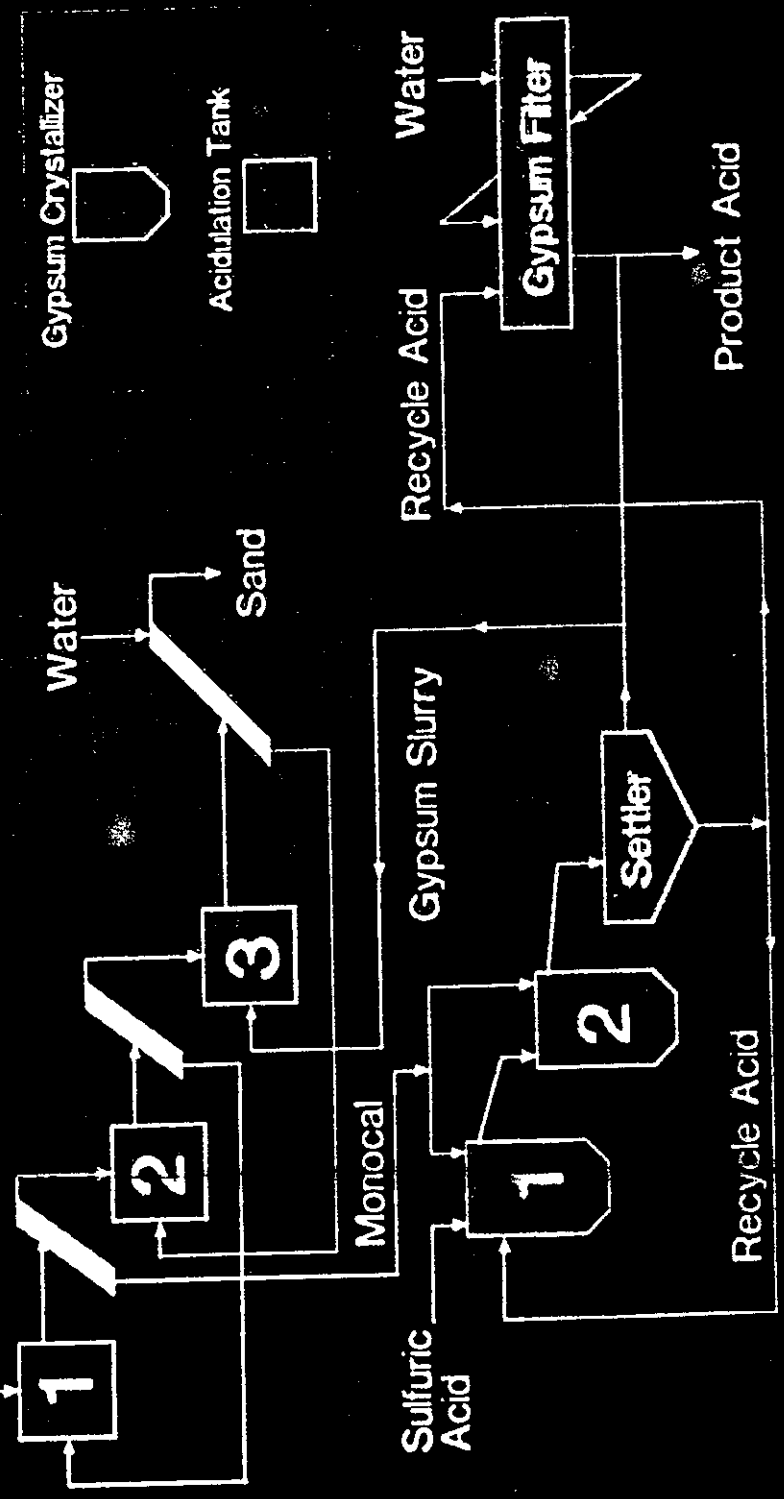


FIGURE 10

MONO-POTASSIUM-PHOSPHATE TYPICAL ANALYSIS

<u>Element</u>	<u>Analysis - %</u>
P2O5	51.42
K	28.54
CL	0.0160
SO4	0.7900
FE	0.0019
AL	0.0090
MG	0.0012
F	Less than 0.0050