Phosphate Testing

for evaluation of

Raw Material Suitability & Project Feasibility

by

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ABSTRACT

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In a world where economics is becoming more and more a governing factor in any development process, the testing of a phosphate prior to plant design is now becoming an important part of the feasibility phase of a project. Economic factors have also meant that the number of companies capable of doing phosphate testing is also declining. Licensing organizations with production facilities for phosphoric acid can offset some of the costs of maintaining this useful tool as it is often of interest to test alternative phosphates as part of the optimization of raw material costs for their own unit.

The main reasons for the testing of a phosphate are not necessarily the same for each project. Some of the reasons are listed below: -

- Equipment sizing
- Performance testing, definition of guarantees
- Corrosion testing, definition of materials of construction
- Acid quality, analysis and/or sample for downstream testing
- Physico-chemical properties of acid, vapor pressure density etc.
- Evaluation of post-precipitation and clarification, important for MGA
- Production of samples of gypsum/hemihydrate for further study

Which of these factors are important in any specific case depends on the prior knowledge of the phosphate and/or its similarity to other known phosphates.

The final product of a fertilizer complex has in the past often been decided before the phosphate was tested, the production of batches by-products based on the produced acid can be made.

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Introduction

The feasibility of any phosphoric acid or phosphate fertilizer complex containing a phosphoric acid plant is highly dependent on the performance of the phosphoric acid unit which in itself is a function of the characteristics of the phosphate being used.

In the design of a new phosphoric acid unit the choice of phosphate is a highly critical one. In a mine site case the level of beneficiation or pretreatment of a phosphate can have enormous impact on the overall profitability of the phosphoric acid unit. In a unit purchasing phosphate from a supplier the initial choice of which phosphates can be treated and the subsequent selection of a specific phosphate has just as much importance.

Phosphoric acid production companies can more easily justify the investment in a pilot-plant than engineering companies. In our case the double justification of being a production company and a process licenser means than although the overheads of maintaining such a facility are relatively large the unit also serves the production department and in any case the personnel can be part of a general R&D group and as such the overheads are easily maintained at a reasonable level.

In our plant at Engis in Belgium we operate a Dihydrate/Hemihydrate, Central-Prayon process which produces acid for two purified acid plants and at the same time has to produce a Calcium Sulfate by-product sufficiently pure for a downstream plaster plant belonging to the German company Knauf. This double task of producing an acid with the minimum of impurities and at the same time a pure Calcium Sulfate means that the constraints on phosphate selection are considerable. In fact no one phosphate is able to satisfy both constraints at the same time. This means that at all times we are using a mix of phosphates and the split of impurities between the liquid and solid phases is of very great importance.

With the desire to purchase the cheapest phosphates that comply totally with our stringent requirements, the cost of transport to our inland site also being of great importance, the study of the split of impurities in pilot-plant for any phosphate or blend of phosphates is important prior to any industrial test or the signing of a long term contract.

Equipment Sizing & Elaboration of Design Data

The licensing arm of Prayon has been building plants all over the world since the 1950's. At the beginning and still today the design of units based on unknown phosphates or relatively new qualities of known phosphates has been an important part of the licensing activity. A list of the phosphates tested is attached in Annex 1. The most important factor being the sizing of the equipment and the process guarantees to be offered. The relative size of Attack and Filtration sections being crucial in the design of a unit that the operating company can have confidence in not solely for the period of the test-run but also for the life of the plant. The product P_2O_5 strength defining the size of the concentration unit and the utility consumption values.

The aspect of Materials of Construction selection is also covered by the simultaneous corrosion testing of various alloys during the pilot-plant test. The elaboration of physico-chemical data during the test also enables the vapor pressure, density and viscosity of the various acid and slurry streams to be determined which is very important for subsequent design work.

Project Definition

Evaluation of a variety of phosphate qualities is also important in a mine site phosphoric acid plant. This can be during the feasibility study of a new project or the re-evaluation of raw materials in the case of an existing plant. So much is talked of the optimization of cost from mine to farmer, but so rarely is this aspect really taken into full consideration.

The level of beneficiation of any phosphate be it simply washing, flotation or thermal treatment has a considerable effect on the overall economics. Once again I must repeat that it is not the BPL or P_2O_5 content of a phosphate that has the main effect on the production cost but it is the CaO/P_2O_5 ratio. However the effect of the impurities on the quality of final products is also important.

Calcination removes some of the organic matter but the Calcium is still present unless it is washed out and if it is still present it will consume Sulfuric Acid. Low temperature calcination can leave sulfides in the phosphate which will eventually cause corrosive conditions within the reaction slurry. For one client in the Middle East we studied the behavior of phosphates treated thermally in various ways in order to optimize the beneficiation/chemical process as a whole. Some information on the different behavior in phosphoric acid production between Calcined and Non-calcined phosphates is mentioned in the section on Case Studies. The comparative cost of using additives, both organic and inorganic, on the production cost can also be evaluated. The use of flocculents in the phosphoric acid production step instead of calcination of the phosphate prior to processing can also be an interesting study.

The use of crystal habit modifiers can also be important where a factory is required to change from its design phosphate to an alternative phosphate with a poorer filterability. The cost of purchasing additional filter area with all its ramifications or the use of an organic or inorganic habit modifier can be weighed up against the capital cost of a new filter or even the possibility of blending phosphates to improve the filterability.

The downstream use of the phosphoric acid also has an effect on the level of beneficiation required although one must say that ideally it should be the inverse, before defining a project based on a captive phosphate the product should be selected based on the ease of beneficiation of the phosphate. One example of this would be the mine site construction of a phosphoric acid plant based on a high aluminum phosphate like Florida, Togo or Senegal. The high aluminum level of all these phosphates is a fact of life the reduction of this impurity being either expensive or wasteful or both. Thus the phosphate should be treated essentially as is and the inevitable post-precipitation after concentration is a fact of life. Thus a project that is based on **solely** the production of MGA means that the plant will be forced to have a sludge recycle system that will complicate the life of the production people for the rest of the life of the plant.. The installation of a small unit to produce powder MAP or TSP would provide the essential purge for these impurities reducing production problems and at the same time providing a low cost fertilizer for local use.

A similar contradiction also applies to the tact that the Florida Industry have confronted the problem of meeting the DAP specification for many years. Maintaining this specification and continuing to insist on the fact that they should produce DAP with the 18-46-0 specification has made their life difficult. The production of "DAP" with a 16-48-0 specification or MAP would reduce the overall production cost and more importantly reduce the wastage of this non-renewable element. The P_2O_5 is better fed to the field than left in slimes dumps in Florida. As the US industry is that market leader it is you here in Florida, now that the numbers of producers can be counted almost on one hand, that have to get together to create the changes necessary for the world industry to be more environmentally friendly and at the same time be more responsible with respect to this precious non re-newable element.

Thus a pilot-plant can produce acid samples for the production of test quantities of downstream products and even allow the making of new non-standard "special" products for greenhouse or field tests.

The other important aspect of pilot-testing is the evaluation of the gypsum. This is also a point that is sometimes forgotten. The production of gypsum samples of downstream use as a by-product or simply to determine data on its behavior for the design of a stack is also an important aspect. So often after the test the client suddenly asks if we still have a sample of gypsum and not always are we able to find the amount required. In one case many years ago, which was not at Prayon, an additional test was made about 12-18 months after the main test purely to make a gypsum sample for the stack design.

Case Study

This case study taken from the files of Prayon shows some of the decisions that might be involved in the selection of a phosphate feed for a particular mine site unit and the operating parameters and performance applied to each of the phosphates to optimize each solution, see Annex 1 for a list of phosphates tested.

Preferably the operation of the pilot-plant at Prayon is normally 24 hours per day, this does make the test somewhat more expensive than the alternative 16-hour per day alternative sometimes adopted when the client is "tight for cash".

The operation of a pilot-plant on an 8-hour per day regime is hardly acceptable statistically as the plant is only just getting into crystal equilibrium as it shuts down. One of the most difficult elements to follow in the pilot-plant is fluorine and the 24-hour per day operation is the one that gets closest to the actual distribution to be found in the industrial unit.

A pilot-plant test in any case is an expensive exercise but the results do really have an even larger financial impact when the industrial unit is in operation. Thus money should be well spent getting the most out of the investment. Thus we believe that the benefits of investing in a 24 hour/day 5 days per week test can increase the levels of confidence in the results and is worthwhile to ensure the economic success of the industrial unit where the numbers are so much bigger.

Normally, prior to testing a number of characterization tests are executed. Often a mineralogical characterization of the phosphate is made , unless the phosphate origin is considered to be well known. Followed with a full chemical and screen analysis. Also the "Potential Solubilization Index" - a proprietary PRAYON test to give a preliminary indication of the distribution of any particular element between the acid and the gypsum, is determined although this can only be used as a preliminary indication of the split of impurities. Obviously the real distribution can only be determined after a full pilot-scale test.

Based on these results normally a single tank design is used to evaluate the phosphate but for more complex or those more sensitive to sulfate the use of a low sulfate zone where the phosphate is added followed with a higher sulfate zone to minimize co-crystallized losses and improve filterability can give better results.

The following results, Table 1 a,b &c, contains historical data from a test selected from our database to demonstrate these effects.

In this particular case study the test program was to test in Dihydrate mode the Calcined phosphate, the Un-calcined phosphate (with and without flocculent) and then in the Calcined phosphate in the Hemihydrate mode.

In this particular case with a fairly fine calcined phosphate it was decided to initially run an Iso-sulfate system. Although the sensitivity of calcined phosphates to sulfate causing inhibition and "coating" is well known it was felt that the fine grind would compensate for this effect. In reality the results shown in Column 1 of Table 1 show that the Attack efficiency was very low at 94.9%, the main loss being as unreacted phosphate with 0.86% P_2O_5 on Anhydrite basis being the loss in the gypsum while the cocrystallized was 0.44%.

These results showed that the reactor design to be selected for the second week should be one that allowed low sulfate where the phosphate was fed and a higher sulfate in the second part of the reaction section. In this second week with 1% SO_3 in the first zone of attack and 1.4% SO_3 in the second part of the attack (Column 2 of Table 1) one can see that this gave the desired results with the mean analyses being 0.4% P_2O_5 for the unreacted and 0.55% as cocrystallized. This gave an attack efficiency of 96.3% and a process efficiency of 95.1%.

During the third week un-calcined phosphate was treated initially with an Iso-sulfate design holding the sulfate at 0.9 % SO_3 and results are tabulated in Table 1 Column 3. The results from this weeks operation, where no flocculent was used, showed that the unreacted phosphate was low (0.13%) but due to the low sulfate the cocrystallized loss was high (0.82%). However even though the crystals were well formed the filtration rate was similar to that obtained during the first two weeks, of the order of 5.7 mtpd P_2O_5/m^2 (0.58 stpd P_2O_5/ft^2) obviously hampered by the organics present. Visibly the slurry was very viscous and difficult to filter.

Thus once again a sulfate gradient technique was tried, this time still with the uncalcined rock and no flocculent, in an attempt to maintain a low total insoluble loss. In the fourth week the operating parameters were set at 1.1% SO_3 in the first zone and 1.5% in the second zone. This alteration had the desired effect maintaining a low unattacked value of 0.14% while reducing the cocrystallized loss to 0.59%, see Column 4. Thus the total insoluble loss was reduced from 0.95% during the third week to 0.73% in the fourth week. Also the water soluble decreased to 0.42% giving a total loss of 1.15% and a gypsum efficiency of 95.5%. The filtration rate was a little better.

In the fifth week we tried using flocculents and an even higher sulfate level and the best results in showed a higher filtration rate at 7.8 mtpd P_2O_5/m^2 (0.80 stpd P_2O_5/ft^2), an increase of about 35% compared with the values of 5.7 to 5.8 mtpd P_2O_5/m^2 from the previous four weeks of operation. The higher sulfate had almost no effect on the total insoluble losses but the distribution was changed. The co-crystallized decreased from 0.59 to 0.42% P_2O_5 and the unreacted increased from 0.14 to 0.3% P_2O_5. The water soluble loss did increase from 0.42 to 0.58% P_2O_5 probably due to the more open texture of the cake. Thus the overall cake efficiency was 94.9%.

Before starting the hemihydrate series of tests one had to expect poor filterability due to historical data with the North Carolina calcined phosphate in hemihydrate tests. The results without additives, shown in Column 6 of Table 1 a-b-c, as expected not very good at 3.0 mtpd P_2O_5/m^2 (0.80 stpd P_2O_5/ft^2). The insoluble losses totaled 1.4% and giving a reaction efficiency of 95.0% while the water soluble at 0.6% P_2O_5 caused the overall cake loss to be 92.5%. Further tests could be made using lower strengths and/or additives to improve filterability.

Samples of product acid are concentrated to the desired strength and clarification tests made if required. Acid and gypsum samples can be retained for further study or testing for products or by-products.

The interpretation of the results and the writing of a report on the process issues follows. This is the most important part of the test and reference to a database of past results is essential to enable good scale up of the results to the industrial case. In fact anyone can do a pilot-plant test as it is just an assembly of "pots and pans" but it is the interpretation of data based on previous experience that is required for good interpretation of the data.

Having now completed the first series of tests and a report made the preliminary evaluation of the results can be made for any prospective project and a full economic analysis made of the alternatives. Eventually additional tests may be required to confirm or optimize the results of the selected solution.

Summary

Expertise and experience are required to interpret data from a test a databank of previous experience is necessary to have a high level of confidence in the results.

Each specific test can be tailored to the client's requirements and the inclusion or deletion of certain aspects obviously has a great effect on the price. Once again it must be repeated that dollars spent at this time can save millions once the plant is built if the right decisions can be made based on the results.

Table 1a - Test results - Attack Section with calcined and un-calcined phosphate

		PRAYON Dihydrate Mk.4					PRAYON PH11 HH
		Calcined Iso-sulphate	**Calcined with Sulphate Gradient**	**Un-Calcined Low Sulphate**	**Un-Calcined with Sulphate Gradient**	**Un-Calcined High Sulphate plus flocculent**	**Un-Calcined Hemihydrate**
		Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Attack data :							
Phosphate: P_2O_5, dry basis	%	33.1	33.1	33.1	33.1	33.1	33.1
Phosphate: CaO, dry basis	%	45.5	45.5	45.5	45.5	45.5	45.5
Temperature slurry #1	°C	77	77	79	81	82	91
Temperature slurry #1	°F	170	171	175	178	179	196
Slurry : SO_3 #1	**%**	**1.5**	**1.0**	**0.8**	**1.1**	**1.6**	**0.6**
Temperature slurry #2	°C	74	77	78	81	81	85
Temperature slurry #2	°F	164	171	172	178	178	185
Slurry : SO_3 #2	**%**	**n/a**	**1.4**	**n/a**	**1.5**	**1.8**	**1.4**
Product Acid : P2O5	%	26.3	27.7	29.1	27.0	28.2	42.6
Crystal water - Dry basis 50°C - 122°F	%	18.6	18.7	18.7	18.7	18.4	6.0
P_2O_5 cocrist. Dry Anhydrite basis	%	0.44	0.55	0.82	0.59	0.42	1.10
P_2O_5 unreact.- Dry Anhydrite basis	%	0.86	0.40	0.13	0.14	0.30	0.30
Total insoluble P_2O_5 Dry Anhydrite basis	**%**	1.30	0.95	0.95	0.73	0.72	1.40
Process Recovery (ATT) as P_2O_5	**%**	**94.9**	**96.3**	**96.3**	**97.1**	**97.2**	**95.0**

Table 1b - Test results - Filtration tests, calcined and un-calcined phosphate

		PRAYON Dihydrate Mk.4					PRAYON PH11 HH
		Calcined Iso-sulphate	**Calcined with Sulphate Gradient**	**Un-Calcined Low Sulphate**	**Un-Calcined Sulphate Gradient**	**Un-Calcined High Sulphate plus flocculent**	**Un-Calcined Hemihydrate**
		Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Slurry : SO_3 #1	%	**1.5**	**1.0**	**0.8**	**1.1**	**1.6**	**0.6**
Slurry : SO_3 #2	%	n/a	**1.4**	n/a	**1.5**	**1.8**	**1.4**
Product Acid : P2O5	%	26.3	27.7	29.1	27.0	28.2	42.6
Weight slurry	g	1030	1199	1163	873	808	998
Surface Filter	m^2	0.01	0.01	0.01	0.01	0.01	0.01
Surface Filter	ft^2	0.108	0.108	0.108	0.108	0.108	0.108
Vacuum mean	mm Hg	500	500	500	500	500	500
Vacuum mean	in Hg	20	20	20	20	20	20
Weight cake (dry anhydrite basis)	g	294	335	364	284	260	240
CaO in cake Anhydrite basis	%	37.2	35.9	36.5	37.4	37.4	37.8
Total insoluble P_2O_5 Dry Anhydrite basis	**%**	1.30	0.95	0.95	0.73	0.72	1.40
P_2O_5 W.S. - Dry Anhydrite basis	%	0.62	0.31	0.46	0.42	0.58	0.60
Total P_2O_5 in cake Dry Anhydrite basis	**%**	1.92	1.26	1.41	1.15	1.30	2.00
Process Recovery (ATT) as P_2O_5	**%**	94.9	96.3	96.3	97.2	97.2	95.0
Process Recovery (ATT+FILT) as P_2O_5	**%**	92.5	95.1	94.5	95.5	94.9	92.5
Crystal water - Dry basis 50°C - 122°F	%	18.6	18.7	18.7	18.7	18.4	6.0
Product Acid : time t_p	sec	20	15	14	8	7	35
1st wash : time t_1	sec	47	44	77	40	26	54
2nd wash : time t_2	sec	24	22	35	25	11	16
3rd wash : time t_3	sec	n/a	n/a	n/a	n/a	n/a	7
Total Cycle/2 wash.: time = T_{C2}' (incl. drainage time)	sec	117	108	160	94	63	n/a
Total Cycle/3 wash.: time = T_{C3}' (incl. drainage time)	sec	n/a	n/a	n/a	n/a	n/a	136
Cake thickness	mm	37	45	48	34	35	25
Cake thickness	in	1.45	1.78	1.89	1.34	1.38	0.98
Scale-up factor (ind.)		n/a	n/a	n/a	n/a	n/a	n/a
Industrial cycle time	**sec**	**100**	**100**	**100**	**100**	**100**	**100**
Filtration Rate INDUSTRIAL - 2 washes	**mtpd P_2O_5/m^2**	**5.7**	**5.8**	**5.7**	**5.8**	**7.8**	n/a
Filtration Rate INDUSTRIAL - 3 washes	**mtpd P_2O_5/m^2**	n/a	n/a	n/a	n/a	n/a	**3.0**
Filtration Rate INDUSTRIAL - 2 washes	**stpd P_2O_5/ft^2**	**0.58**	**0.59**	**0.58**	**0.59**	**0.80**	n/a
Filtration Rate INDUSTRIAL - 3 washes	**stpd P_2O_5/ft^2**	n/a	n/a	n/a	n/a	n/a	**0.31**

Table 1c - Overall test results - calcined and un-calcined phosphate

		PRAYON Dihydrate Mk.4					PRAYON PH11 HH
		Calcined Iso-sulphate	**Calcined with Sulphate Gradient**	**Un-Calcined Low Sulphate**	**Un-Calcined Sulphate Gradient**	**Un-Calcined High Sulphate plus flocculent**	**Un-Calcined Hemihydrate**
		Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Product Acid : P2O5	%	26.3	27.7	29.1	27.0	28.2	42.6
P_2O_5 cocrist. Dry Anhydrite basis	%	*0.44*	*0.55*	*0.82*	*0.59*	*0.42*	*1.10*
P_2O_5 unreact.- Dry Anhydrite basis	%	*0.86*	*0.40*	*0.13*	*0.14*	*0.30*	*0.30*
Total insoluble P_2O_5 Dry Anhydrite basis	**%**	**1.30**	**0.95**	**0.95**	**0.73**	**0.72**	**1.40**
P_2O_5 W.S. - Dry Anhydrite basis	%	**0.62**	**0.31**	**0.46**	**0.42**	**0.58**	**0.60**
Total P_2O_5 in cake Dry Anhydrite basis	**%**	**1.92**	**1.26**	**1.41**	**1.16**	**1.30**	**2.00**
Crystal water - Dry basis 50°C - 122°F	%	18.6	18.7	18.7	18.7	18.4	6.0
Process Recovery (ATT) as P_2O_5	**%**	**94.9**	**96.3**	**96.3**	**97.1**	**97.2**	**95.0**
Process Recovery (ATT+FILT) as P_2O_5	**%**	**92.5**	**95.1**	**94.5**	**95.5**	**94.9**	**92.5**
Industrial cycle time	**sec**	**100**	**100**	**100**	**100**	**100**	**100**
Filtration Rate INDUSTRIAL - 2 washes	**mtpd P_2O_5/m^2**	**5.7**	**5.8**	**5.7**	**5.8**	**7.8**	**n/a**
Filtration Rate INDUSTRIAL - 3 washes	**mtpd P_2O_5/m^2**	n/a	n/a	n/a	n/a	n/a	3.0
Filtration Rate INDUSTRIAL - 2 washes	**stpd P_2O_5/ft^2**	**0.58**	**0.59**	**0.58**	**0.59**	**0.80**	n/a
Filtration Rate INDUSTRIAL - 3 washes	**stpd P_2O_5/ft^2**	n/a	n/a	n/a	n/a	n/a	**0.31**

ANNEX 1

List of phosphate tests as of June 1997

LIST OF PHOSPHORIC ACID MANUFACTURING TESTS

PERFORMED BY PRAYON

More than 270 tests have been carried out in the PRAYON laboratories over the past 40 years with the purpose of studying and appraising the suitability of phosphate rocks for making phosphoric acid by the dihydrate wet process.

Most of well-known commercial grade rocks of the world have been experienced one or several times: eighty-two of them are mentioned in the list.

Many rocks have also been tested in various experimental states of beneficiation: run-of-mine, screened, washed, floated, calcined, or uncalcined, fines from drying, ...

Our experience practically embodies the whole range of rock grades : from the high apatite concentrate at 39,5 % P_2O_5 to the low experimental sample with a 25 % P_2O_5 content.

Some very particular ores have been the subject of extensive researches, which led to a successful approach of processing these ores.

Among them, the following unusual rocks :

- **several Brazilian samples containing up to 24 % SiO_2 and 6,5 % Feral;**
- **a Brazilian uranium-phosphate ore containing 14 % to 16 % CO_2;**
- **a Finnish iron-phosphate ore containing 7,7 % Feral;**
- **a Russian (Kara-Tau) ore containing 25 % P_2O_5 - 16,5 % SiO_2 - 2,7 % MgO - 8,1 % CO_2.**

More recently we had the opportunity of making full reports on the treatment of a few phosphates of the day :

- **Dagbati and fines from Togo,**
- **Abu-Tartur from Egypt,**
- **Slimes and fines of Taïba from Senegal,**
- **Gallao from Peru,**
- **Nauru,**
- **Chinese Phosphates from Yunnan, Hebei, Hubei and Guizhou Provinces.**

Our bench-scale testing procedure always includes :

- **the preparation and grinding of the sample;**
- **the sulphuric acid attack of the rock;**
- **the filtration and washing of the gypsum;**
- **the corrosion tests on several materials;**

with the research and optimization of all operating parameters of these sections.

Very often the following operations are also achieved :

- **the concentration of the product acid;**
- **the aging, clarification and decantation of the concentrated acid.**

As mentioned above, the enclosed list relates to the tests run out as per the conventional PRAYON Dihydrate Gypsum Process and other PRAYON Processes (the two-stages (dihydrate-hemihydrate) phosphoric acid process, High Strength acid, ...).

Other PRAYON laboratory activities, for which tens of studies have been done, includes other processes or uses of phosphoric acid, such as :

- **uranium recovery from phosphoric acid;**
- **cleaning-up and purification of phosphoric acid;**
- **post-treatment and uses of by-product dihydrate and hemihydrate gypsum.**

LIST OF PHOSPHATES TESTED BY PRAYON LABORATORIES

I. NORTH AMERICA

CENTRAL FLORIDA

Number of tests carried out : 69

These tests practically cover the whole range of phosphate rocks mined and beneficiated in Florida.

Most of the usual commercial grade rocks appear in this list, for instance :

AGRICOLA AREA BARTOW CHICORA CLEAR SPRINGS CORONET	FORT MEADE FOUR CORNERS HOOKER'S PRAIRIE KINGSFORD MULBERRY	NORALYN NICHOLS PALMETTO PAYNE CREEK PLANT CITY PIERCE

NORTH FLORIDA

Number of tests : 1

	SWANEE RIVER	

SOUTH FLORIDA

Number of tests : 9
including :

HARDEE COUNTY	DUETTE MINE (Manatee)	MANATEE COUNTY

SOUTH CAROLINA

Number of tests : 2
including :

	PINE MOUTAIN	

NORTH CAROLINA

Number of tests : 26
including :

	various floated, uncalcined or calcined rocks.	

TENNESSEE

Number of tests : 1

MONTANA

Number of tests : 1

WESTERN U.S.

Number of tests : 12
including :

CONDA calcined	**VERNAL** **ALUNITE FROM IDAHO**	**CONDA uncalcined**

MEXICO

Number of tests : 2

BAJA CALIFORNIA	**SAN JUAN DE LA COSTA**	

II. SOUTH AMERICA

PERU

Number of tests : 5
including :

GALLAO	**SECHURA**	

VENEZUELA

Number of tests : 2

	RICEITO	

BRAZIL

Number of tests : 11
including

ARAXA - MG **TAPIRA - MG**	**JACUPIRANGA - SP** **COROPHOSPHATOS - MG**	**ITATAIA - CE** **CATALAO - GO**

III. NORTH AFRICA

MOROCCO

Number of tests : 22
including

BEN GUERIR	KHOURIBGA YOUSSOUFIA	BOU CRAA

TUNISIA

Number of tests : 6
including :

M'DILLA	REDEYEF METLAOUI	MOULARES

ALGERIA

Number of tests : 4

	DJEBEL ONK	

IV. WEST AFRICA

SENEGAL

Number of tests : 7
including :

TAIBA TAIBA FINES		THIES

TOGO

Number of tests : 6
including :

DAGBATI AREA **FINES OF DAGBATI**	**HAHOTOE AREA**	

V. SOUTH, CENTRAL & EAST AFRICA

UGANDA

Number of tests : 3
including :

TORORO		**SUKULU**

EGYPT

Number of tests : 4
including :

WEST SEBAYA **EAST SEBAYA**		**ABU TARTUR** **SAFAGA**

REPUBLIC OF SOUTH AFRICA

Number of tests : 8
including :

PHALABORWA PYROXENITE	**PHALABORWA FOSKORITE**	

VI. MIDDLE EAST

JORDAN

Number of tests : 8
including :

RUSEIFA	EL HASSA	ESHIDIYA

IRAQ

Number of tests : 10

	AKASHAT	

SYRIA

Number of tests : 3

	KNEIFISS EASTERN MINE	

VII. ASIA

NORTH VIETNAM

Number of tests : 2

	LAO KAI	

CHINA

Number of tests : 15
including :

WENGFU **HUANGMAILING**	**JIANGCHUAN** **JINING** **KWANGCHOW**	**DAYOUKOU** **FAN SHAN**

INDIA

Number of tests : 3
including :

	RAJASTHAN **MATON**	

VIII. PACIFIC ISLANDS

Number of tests : 8
including :

CHRISTMAS ISLAND	**NAURU**	**MAKATEA**

IX. EUROPE

U.S.S.R.

Number of tests : 4
including :

KOVDOR	**KOLA APATITE**	**KARA TAU**

SWEDEN

Number of tests : 2

	L.K.A.B. APATITE	

FINLAND

Number of tests : 4

	SOKLI APATITE	

X. AUSTRALIA

Number of tests : 2

	LADY ANNIE MINE **DUCHESS MINE**	

ANNEX 2

Photos of the Prayon Pilot-plant

Taken April 1998

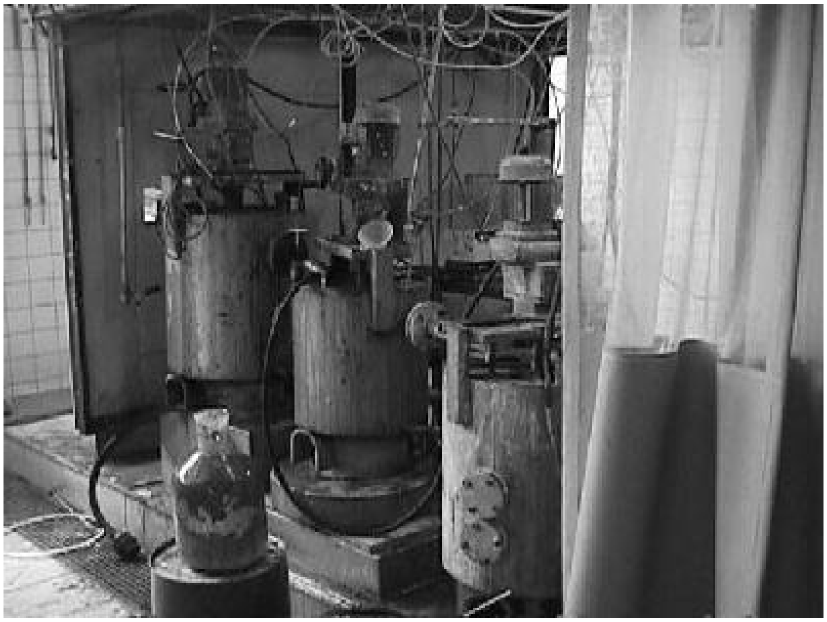

Figure 1 - General view of the Pilot-plant

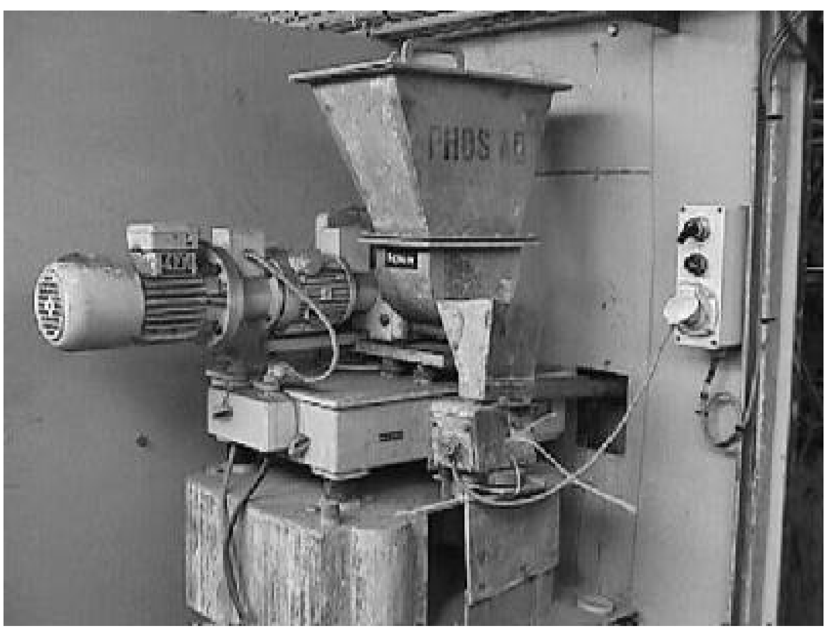

Figure 2 - Phosphate feeder

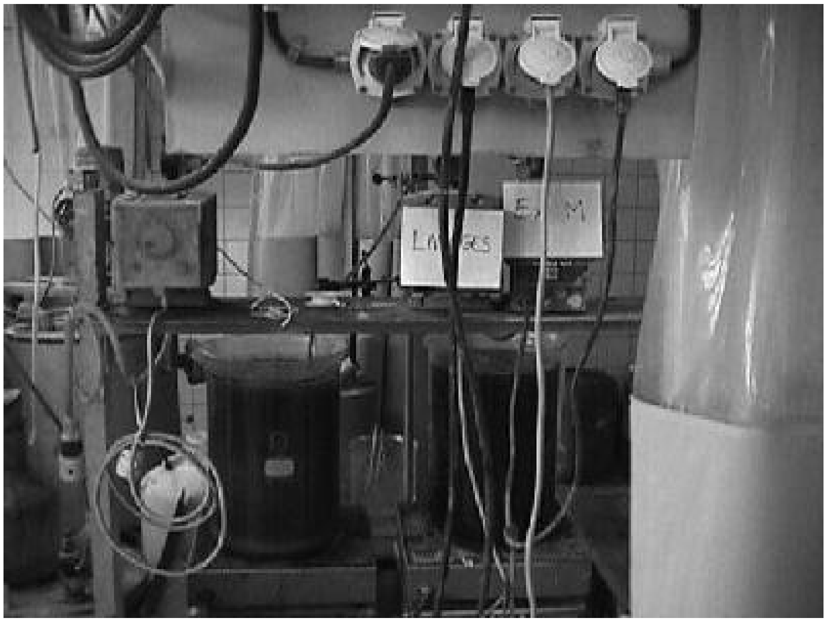

Figure 3 - Sulphuric and return acid dosing pumps

Figure 4 - Filtration of produced slurry

Figure 5 - Filtration test cell

Figure 6 - Clarification test on concentrated acid