

ISMA* Technical Conference

Orlando, Florida, USA
23-27 October 1978

**In 1982, the name of the International Superphosphate Manufacturers' Associations (ISMA) was changed to International Fertilizer Industry Association (IFA).*

FISONS' EXPERIENCE ON THE EFFECT OF PHOSPHATE ROCK

IMPURITIES ON PHOSPHORIC ACID PLANT PERFORMANCE

N Robinson, Fisons Limited UK

Introduction

World production of phosphoric acid from phosphate rock continues to rise. Currently, about 26 million tonnes per annum are produced and this figure is expected to grow to more than 30 million tonnes by the early 1980's.

Already there is concern that in meeting this demand a reduction in quality of phosphate rocks will occur, not only in P_2O_5 concentration, but also in the nature and content of impurities present. In the longer term these problems will become more acute, and lower standards will have to be accepted by phosphoric acid manufacturers unless technology can be advanced to meet the new situation.

Many of the impurities present in phosphate rocks affect phosphoric acid plant performance in some way; the degree of influence depends not only on individual concentration levels, but also on relative levels in relation to interactions. The effects of certain impurities are well known and understood; other effects, particularly those involving minor components, are less clear, and this applies particularly to changes in crystal growth, crystal habit and the precipitation of compounds other than calcium sulphate.

Fisons' Experience

Fisons is a major manufacturer of phosphoric acid in the United Kingdom consuming more than three-quarter of a million tonnes of phosphate rock annually. Over the years phosphate rocks from many sources have been processed but those originating from Morocco and Florida, USA have predominated. Fisons Fertilizer Division operates three phosphoric acid plants, producing about one-quarter of a million tonnes of P_2O_5 per annum by the Dihydrate route. One of these plants is to Fison's own design.

Since 1958 a considerable amount of work has been carried out in the field of phosphoric acid technology at the Company's Fertilizer Research Centre at Levington. Originally this work was aimed at improving the performance of the Division's production plants and significant progress has been achieved in this direction. Eventually this work led to the development of new phosphoric acid processes, first, based on the Dihydrate route and later by a new generation of Hemihydrate and Hemihydrate/Dihydrate (HDH) routes. These processes have been licenced to various companies through Fisons Licensing and Consultancy Services in collaboration with Foster Wheeler Corporation, Lurgi Chemie and Huttentechnik GmbH and Davy Power Gas Limited. Currently, 8 Dihydrate plants, 2 Hemihydrate plants and 2 HDH plants are in operation or at different stages of construction. Details of these plants and the phosphate rocks which are processed are given in Table 1.

TABLE 1
PHOSPHORIC ACID PROCESSES LICENCED BY
FISONS LICENCING AND CONSULTANCY SERVICES

<u>Company</u>	<u>Country</u>	<u>Capacity</u> tpa P_2O_5	<u>Type of</u> <u>Process</u>	<u>Rock</u>	<u>Constructor</u>	<u>Start</u> <u>Up</u>
Fisons	UK	75,000	DH	Morocco	Lurgi	1968
AE and CI	South Africa	27,000	DH	Phalaborwa	Davy Power Gas	1970
Windmill	Holland	60,000	HH	Togo	Lurgi	1970
Quimbrasil	Brazil	65,000	DH	Jacupiranga	Davy Power Gas	1973
Trepca	Yugoslavia	50,000	HDH	Morocco	Lurgi	1974
Omia	South Africa	25,000	DH	Phalaborwa	Lurgi	1975
Zletovo	Yugoslavia	50,000	DH	Morocco	Lurgi	1978/ 1979
Sabac	Yugoslavia	75,000	DH	Gafsa	Lurgi	1978/ 1979
HMC	Cyprus	40,000	HH	Syrian	Lurgi	1980
Albright and Wilson	UK	160,000	HDH	Morocco	Lurgi	1980
Kutina	Yugoslavia	160,000	DH	Morocco	Davy Power Gas	1981
Abu Zabaal	Egypt	65,000	DH	Egypt	Lurgi	1981

In parallel with the development of new phosphoric acid processes, laboratory and pilot plant test procedures have been developed to allow phosphate rocks to be assessed for phosphoric acid manufacture. Since 1967 many rocks have been evaluated at Levington Research Station using the Dihydrate and Hemihydrate process routes. These assessments have been carried out for Fisons own use, for other phosphoric acid producers and for phosphate rock mining companies. A list giving the rocks assessed and the process route used is given in Table 2.

TABLE 2
PHOSPHATE ROCKS ASSESSED BY FISON'S FOR THE
MANUFACTURE OF PHOSPHORIC ACID AND PHOSPHATES

<u>Phosphate Rock</u>	<u>Grade</u>	<u>Country</u>	<u>Company</u>	<u>Process</u>	<u>Year</u>
Khouribga	All	Moreocco	Fisons	DH, HH	
Youssoufia	72% BPL	Moreocco	Fisons	DH	1976
Calcined N Carolina	73% BPL	USA	N Carolina Phosphate Corp	DH	1967
Calcined N Carolina	73% BPL	USA	Fisons	DH	1976
Calcined N Carolina	73% BPL	USA	Texas Gulf	DH	1974
Calcined N Carolina	73% BPL	USA	Agrico	HH	1974
Uncalcined N Carolina	73% BPL	USA	Fisons	DH	1978
Syrian	72% BPL	Syria	State/DPG	DH	1969
Syrian	72% BPL	Syria	Hellemic Mining	HH	1977
Sahara	75% BPL	Sahara	Fosbueraa	DH	1970
Sahara	80% BPL	Sahara	Fisons	HH	1974
Jacupiranga	77% BPL	Brazil	Quimbrasil	DH	1970
Lady Annie	74% BPL	Australia	Broken Hill	DH	1970
Phalaborwa	77% BPL	S Africa	Fisons	DH, HH	1975
Langebaan	67% BPL	S Africa	Ancor	DH, HH	1972
Florida	Many	USA	Fisons Occidental Windmill Gardiner	DH HH HH DH	 1972 1972 1977
Araxa	75% BPL	Brazil	Arafertil	DH	1974
LKAB	80% BPL	Sweden	LKAB	DH	1974
Nauru/ Christmas Island	82% BPL	Nauru	Pivot	DH, HH	1975
Nauru					1978

..... continued

TABLE 2 (CONT'D)

<u>Phosphate Rock</u>	<u>Grade</u>	<u>Country</u>	<u>Company</u>	<u>Process</u>	<u>Year</u>
Tapira	85% BPL	Brazil	Titansa	DH	1977
Abu Zaabal	63% BPL	Egypt	Lurgi/DPG	DH	1977
Taiba	80% BPL	Senegal	APC Fisons	DH HH	1977
Kola	82% BPL	USSR	Fisons	DH, HH	1969 1971
Jordan	67% BPL 72% BPL	Jordan	Fisons	DH	1976 1978
Gafsa	63% BPL	Tunisia	Fisons	DH	1970
Togo	80% BPL	Togoland	Windmill/Fisons	DH, HH	1970

DH = Dihydrate Process Route

HH = Hemihydrate/Hemihydrate-Dihydrate Process Routes

The above assessments normally include the manufacture of Superphosphates and Ammonium Phosphates using the phosphoric acid and rock under test.

The determination of corrosion rates of a range of steels normally used to fabricate phosphoric acid plant equipment is also carried out and the assessment includes the measurements of physical properties to aid design.

It has been shown that results from these assessments accurately predict the behaviour of commercial plants thereby allowing data to be used confidently for design purposes. The assessments are also particularly valuable to rock producers in providing an independent evaluation of processing performance.

General Effects of Impurities

Fluorapatite, $\text{Ca}_{10}(\text{PO}_4)_6\text{F}_2$, is a common constituent of most phosphate rocks; substitution for fluorine can sometimes occur by hydroxyl and less frequently by chloride ions giving hydroxyapatite, $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$ or chlorapatite, $\text{Ca}_{10}(\text{PO}_4)_6\text{Cl}_2$.

Apart from phosphate, calcium and fluorine, phosphate rocks contain a wide range of impurities (Table 3) which more often than not affect in some way the chemistry of the 'wet' process and the performance of a phosphoric acid plant.

Calcium carbonate, for example, is often present, sometimes combined with fluorapatite as francolite, $\text{Ca}_{10}(\text{PO}_4)_6\text{F}_2$, CaCO_3 , but more frequently in association with the mined rock in the form of calcite. From either source the calcium carbonate is decomposed, precipitating calcium sulphate and liberating carbon dioxide.



where $x = 0, 0.5 \text{ to } 0.7 \text{ or } 2.0$

Evolution of carbon dioxide can increase the reaction rate by causing disintegration of rock grains and providing an increase in specific surface area. This effect is only likely to be significant in the cases where the calcium carbonate is part of the apatite structure, as in francolite.

A far more common effect of carbon dioxide evolution is the formation of foam which can prevent the wetting of rock particles, affect reaction rate and control, and also cause loss of P_2O_5 due to entrainment of foam by exhaust air in vent or in cooling system. For some rocks, eg Morocco, it is possible to control foaming by the turbulence generated by agitation; if this is insufficient the only solution, apart from calcining or changing the rock source, is to reduce the surface tension of the acid by the use of a defoamer, which increases operating costs.

Carbon dioxide evolution is not the only criterion which determines the extent of foaming. Phosphate rocks usually contain organic matter which sometimes stabilize foam caused by gas evolution. This is illustrated in Figure 1, where foam heights given by Morocco (Khouribga), Florida and Taiba rocks are plotted against time. Khouribga rock can normally be processed without the need of a defoamer because organic matter in this case appears to have a small effect on foam stability. Florida rock, although having a lower carbon dioxide content, requires a defoamer because of the stabilizing influence of organic matter. Taiba rock has a low carbon dioxide content and no defoamer is required. However, this rock contains organic matter which imparts a high stability to the foam and for this reason a severe foaming problem can arise if Taiba is processed with any rock containing even moderate levels of carbon dioxide.

<u>Component</u> <u>% w/w</u>	<u>Khouribga</u>	<u>Youssoufia</u>	<u>Phalaborwa</u>	<u>Tapira</u>	<u>Araxa</u>	<u>Nauru</u>	<u>Florida</u>	<u>Taiba</u>	<u>Togo</u>
P ₂ O ₅	33.4	32.21	36.75	39.1	34.9	38.5	31.6	37.5	36.80
CaO	50.6	51.70	52.11	53.3	46.2	52.4	46.5	51.2	50.5
SO ₃	1.62	1.28	0.17	0.03	2.21	0.03	0.76	0.08	0.17
Al ₂ O ₃	0.43	0.36	0.15	0.48	0.46	0.215	1.26	1.10	1.00
Fe ₂ O ₃	0.20	0.25	0.27	0.73	2.86	0.13	1.44	1.10	1.14
MgO	0.33	0.43	1.06	0.14	0.06	0.25	0.38	0.02	0.06
Na ₂ O	0.70	0.76	0.04	0.12	0.23	0.24	0.64	0.20	0.23
K ₂ O	0.09	0.07	0.05	0.01	0.02	0.04	0.10	0.03	0.05
SrO	0.1	0.1	0.31	0.39	1.11	0.01	0.1	0.08	0.02
F	3.97	4.10	2.20	1.31	2.10	2.66	3.65	3.91	3.84
Cl	0.028	0.03	0.02	0.007	0.004	0.002	0.02	0.05	0.12
SiO ₂	1.92	3.18	2.61	1.03	0.25	0.24	9.50	2.49	3.62
CO ₂	4.51	5.60	3.50	0.55	2.10	2.57	3.67	1.50	1.28
Organic	0.26	1.00	0.03	0.07	0.04	1.13	0.18	0.54	0.14

Table 3: Chemical Analyses of Phosphate Rocks

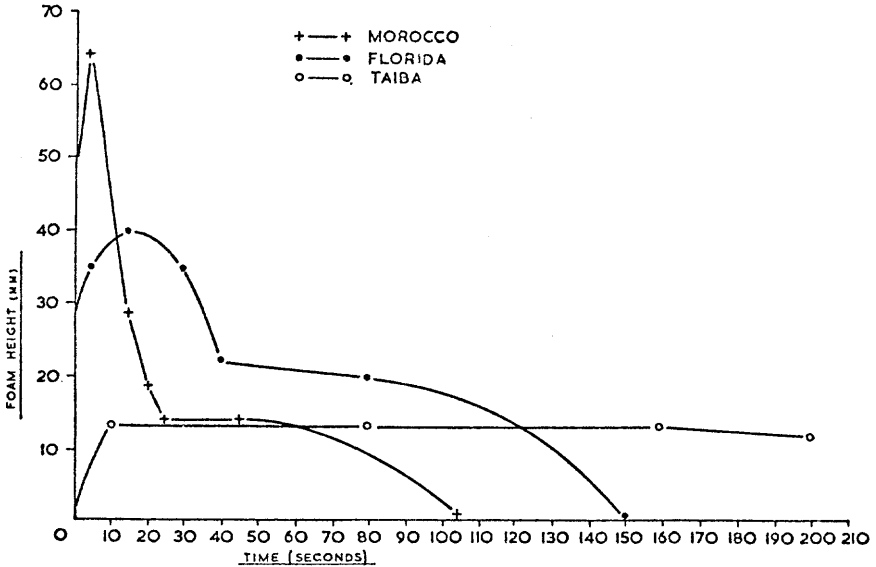
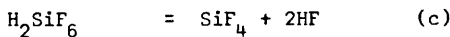
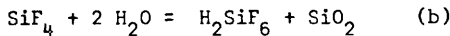
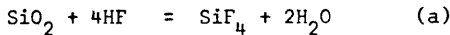


Figure 1: Foaming Characteristics of Phosphate Rocks

Phosphate rocks usually contain silicon in the form of silicates or as quartz. Hydrofluoric acid, produced from the decomposition of the fluorapatite, reacts with the silica at a rate depending on the type of silica present. Silicates, for example, react readily, whereas quartz reacts slowly.

Under the conditions of phosphoric acid manufacture the usual reactions involved following the reaction of silica and hydrofluoric acid are:



In the Dihydrate process the main fluorine reaction which occurs in the reaction system is the formation of fluorosilicic acid by reaction (b). Very little evolution of silicon tetrafluoride occurs by reactions (a) or (c). Silica is also produced by reaction (b) and this is available for further reaction with fluoride ions, or is removed with the precipitated gypsum by filtration.

In Hemihydrate processes, producing 45-50% P_2O_5 acid in the reaction system, fluorine is evolved mainly by way of reactions (a) and (c). As a result, fluorine concentrations in the reaction acid are much lower in these processes compared to Dihydrate processes.

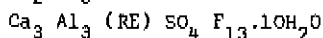
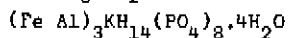
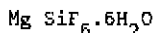
The reaction acid in both types of process will contain fluorine in the form of fluoride and fluorosilicate ions. The quantity and proportion of each will depend on the process and the type of phosphate rock processed. In both cases, however, these impurities will affect process performance.

Fluorosilicate ions react with alkali metals to form hard scales in the reaction, filtration and evaporation stages. The sodium salt and sodium/potassium double salt are the usual forms which are precipitated. Dihydrate processes are particularly prone to this problem, scale being formed in reaction vessels, the filter circuit and in evaporators. Descaling by washing or by manual means reduces plant utilization. Hemihydrate processes producing 45 to 50% P_2O_5 acids, are less prone to scaling, in that no scale is produced in the reaction system and no evaporation is involved. However, as with Dihydrate processes, fluorosilicate scale can be produced in the filter circuit, depending on the concentrations of alkali metals in the rock processed. Two-stage (HDM) processes are less affected than single-stage Hemihydrate processes.

Fluoride ions influence the corrosivity of phosphoric acid and this becomes significant when phosphate rocks contain high amounts of fluoride compared to active silica. Fluoride can also affect dihydrate crystal growth and retard the recrystallisation of hemihydrate to dihydrate.

Cationic impurities can affect dihydrate crystal growth and habit and influence filterability. These effects are further complicated in that interactions with anions, e.g. Fluoride also occur. Cationic impurities also form complex compounds with anions such as phosphate, silicate and fluoride. These compounds can vary in composition due to isomorphous substitution by cationic impurities which may be present in the rock in only trace amounts. The most common cationic impurities are iron, aluminium, magnesium, sodium and potassium, and these elements are mainly responsible for the formation of compounds that slowly precipitate from phosphoric acid forming sludges which complicate acid storage and shipping. The range (1) of complex compounds which can be produced is large; there are no rules which can be applied to predict sludge compositions generally. The composition of the rock will obviously be a significant factor and as the concentrations and range of impurities increase the complexity of sludges which can be produced will also increase.

When processing Florida rock the most common compounds apart from Calcium Sulphate we have identified in acid sludges include:



Apart from complications caused to acid storage and shipping, the formation of sludge can have an adverse effect on the processing performance of a rock. The extent of this effect will depend on the composition and amount of sludge produced, the sludge handling methods employed and the need to recycle sludge to the reaction/filtration systems of the phosphoric acid plant.

Complex compounds can also be produced more rapidly in the reaction system of a phosphoric acid plant and adversely affect plant operation. An example is the formation of complexes of the type $Ca_3 Al_3 (RE) SO_4 F_{13} \cdot 10H_2O$, also referred to above, where 'RE' could be a mixture of rare earths and yttrium. This compound is one of an isomorphous series where Al^{3+} can be replaced by other trivalent ions or by Ca^{2+} and Si^{4+} jointly, and F^- by $(OH)^-$. Compounds of this type have been reported by several workers (2, 3 4) and in each case the crystals could be classified in the cubic system and are octahedral in habit. Typical crystals are shown in Figure 2. Figure 3 illustrates a

filter cloth which has been blinded by octahedral crystals causing loss of filtration capacity.

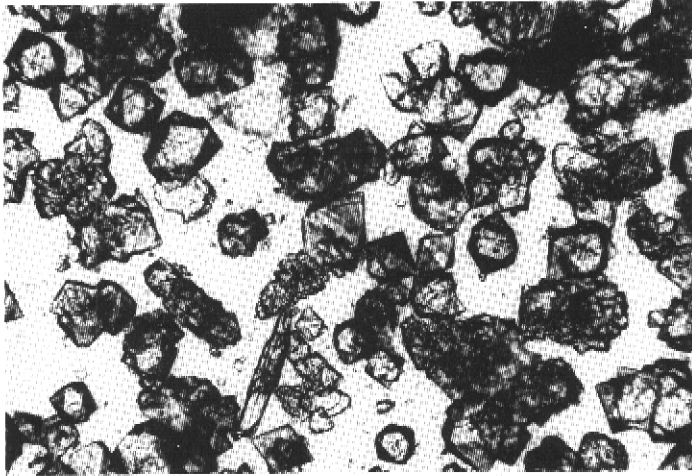


Figure 2: "Octahedral Crystals"

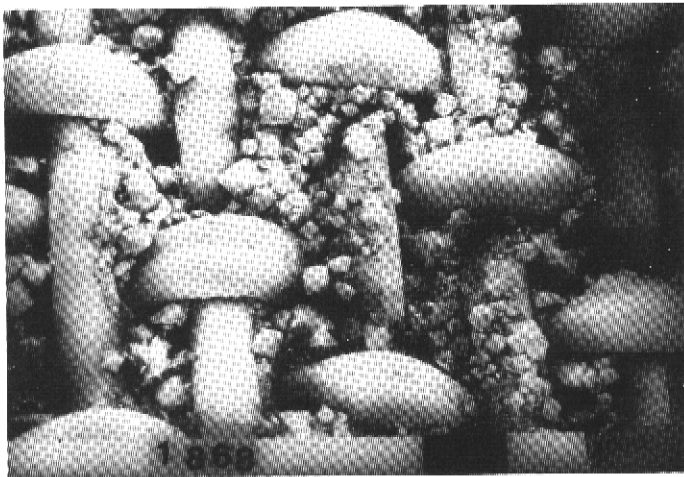


Figure 3: Filter Cloth Blinded by "Octahedral" Crystals

Examples of Impurity Effects

To illustrate the complex behaviour of impurities some examples have been selected from the range of rocks tested at Levinington Research Station and on production plants.

Before considering these examples it should be said that one important conclusion which has been reached from rock assessments is that good performance cannot automatically be guaranteed by processing high grade rocks containing low impurity levels. Although a high grade rock will produce a purer phosphoric acid, there may be disadvantages, such as poor filtration rates, high corrosion rates, etc which would adversely affect production rates and operating costs. Conversely, a lower grade rock may be a good choice from the point of view of processing behaviour, if acid quality is acceptable. In Europe a phosphate rock was generally regarded as "high" grade if it had a P_2O_5 content within the range 33% to 39%. Rocks considered to be "low" grade were those having P_2O_5 contents from 28% to 33%.

Today, rocks containing 30% P_2O_5 or higher are now being regarded as "high" grade and those containing less than 30% P_2O_5 as "low" grade. This downward trend is expected to continue and will inevitably make rock selection by phosphoric acid producers more difficult unless the effects of higher levels of impurities can be predicted.

Phalaborwa rock is one example of a high grade rock which has been mined and processed for many years in South Africa. When used in the Dihydrate process Phalaborwa rock produces small needle-shaped gypsum crystals (Figure 4) which have poor filtration properties. Surface active agents, such as alkyl benzene sulphonates, are effective crystal habit modifiers in the case of Phalaborwa rock, converting the needle-shaped gypsum crystals to rhombic plates (Figure 5) which have superior filtration properties. Phalaborwa rock has a low aluminium content and comparatively low levels of silica and fluorine; it also contains about 0.3% of Strontium expressed as the oxide. These impurities are known to influence the crystal habit of gypsum. Inorganic crystal modifiers, however, have only a small effect on Phalaborwa gypsum compared to the effect of organic modifiers. This behaviour is not generally applicable as with other rocks the reverse effects are often true.

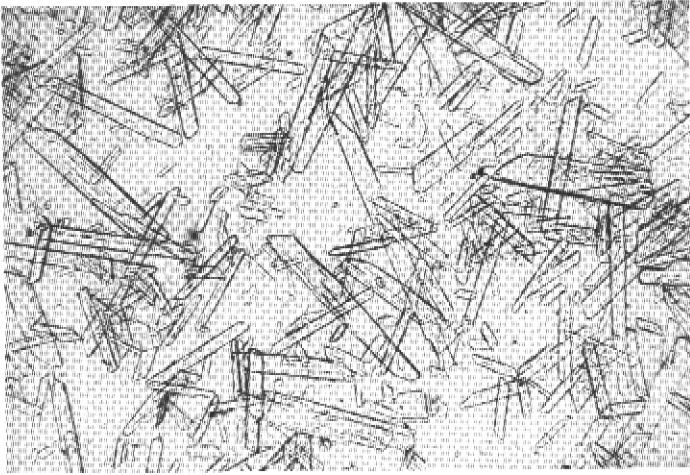


Figure 4: Dihydrate Crystals Produced from Phalaborwa Rock

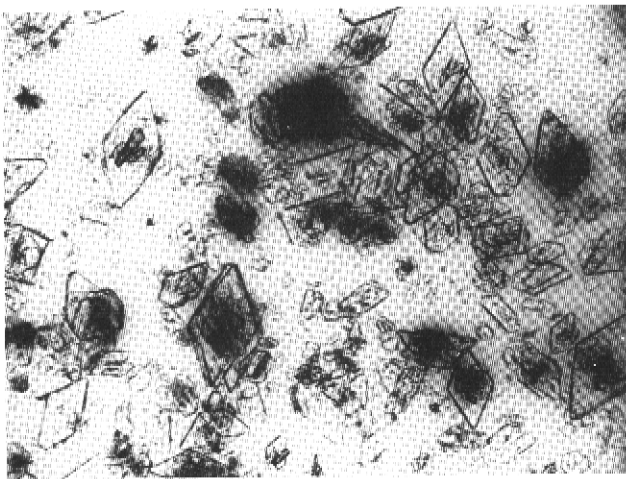


Figure 5: Modified Phalaborwa Crystals

Youssoufia rock, for example, which is mined in Morocco, produces needle-shaped crystals when used in the Dihydrate process (Figure 6). Inorganic modifiers change these crystals beneficially to the rhombic form (Figure 7). Unlike Phalaborwa, organic habit modifiers have little effect on the shape of Youssoufia crystals.

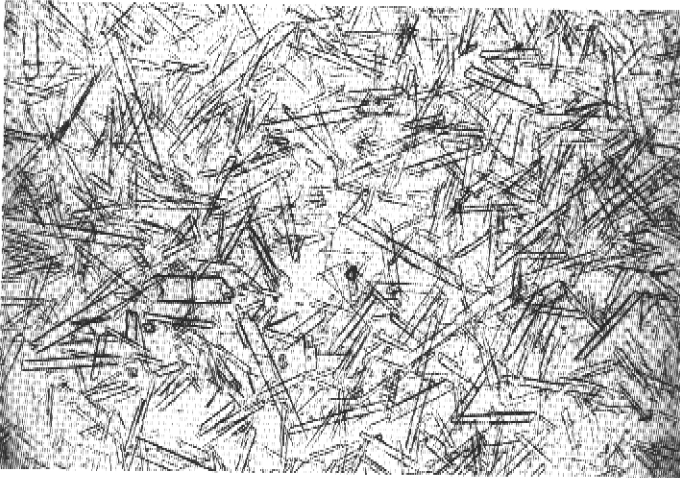


Figure 6: Dihydrate Crystals Produced from Youssoufia Rock



Figure 7: Modified Youssoufia Crystals

Phosphate rocks do not necessarily have to produce gypsum crystals in the rhombic form to achieve good filtration and washing rates. Gypsum filter cakes which have similar specific surface areas will have a higher porosity if the crystals are in the form of needles. To achieve good filtration and washing rates needle crystals need to be comparatively larger than rhombic crystals. This can be achieved by some rocks and not by others. Tapira phosphate rock, for example, which is mined in the State of Minas Gerais, Brazil, produces needle-shaped crystals (Figure 8) when processed in the Dihydrate process. These crystals, however, can be grown to a size which allows good filtration and washing rates to be achieved.

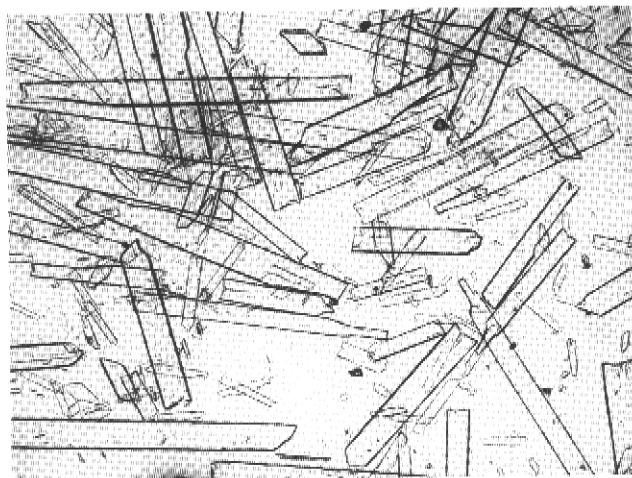


Figure 8: Dihydrate Crystals Produced from Tapira Rock

Araxa phosphate rock, also mined in Brazil, has an unusually high and variable barium content (4%). At the time of testing of this rock there was concern that barium may be present in a form which could seriously affect the particle size distribution of the gypsum filter cake and reduce filtration and washing rates. Alternatively, precipitation of the barium as the sulphate was also possible with the same effect. When tested, however, Araxa rock gave good filtration rates and there was no evidence for any interference accountable to barium. Other rocks containing higher levels of soluble barium could present a different picture.

Phosphate rocks containing high levels of iron have been tested. Examples include Egyptian and Senegal rocks which have Fe_2O_3 contents at about the 2% level. When processed by the Dihydrate or Hemihydrate routes most of the iron will dissolve and remain in the phosphoric acid. At the 2% level or higher, iron will increase phosphoric acid viscosities by 50% or more compared to acids containing 0.5% iron. This will reduce filtration rates, particularly in the case of Hemihydrate processes operating at high acid P_2O_5 concentrations. Rocks containing high levels of iron can produce gypsum crystals in the needle or rhombic form. Although iron can function as a crystal habit modifier its effectiveness depends on the presence of other impurities which may predominate.

Although many impurities present in phosphate rocks can influence the growth and shape of gypsum crystals, there are also other factors which should not be overlooked. Variables such as P_2O_5 and SO_4 concentrations, which are controlled in all phosphoric acid processes, can also play a major part in determining the type of gypsum produced. Crystals generally tend to become smaller as P_2O_5 concentrations increase: changes in crystal shape do not normally occur unless phase changes are inadvertently produced from gypsum to hemihydrate or anhydrite. Sulphate concentrations, on the other hand, can influence both crystal size and shape, particularly with those rocks which contain low levels of impurities which can function as crystal habit modifiers. Morocco rocks, for example, produce crystals which can range from small needles to large rhombic plates, depending on the sulphate concentrations used. Other rocks, for example Florida, are less sensitive to sulphate concentrations due to the influence of more powerful crystal habit modifiers.

Impurities present in rocks, apart from influencing crystal size and shape, also affect the performance of a phosphoric acid plant in other ways. The effects of carbonates and organic matter on foaming has already been discussed in addition to those impurities which are primarily responsible for the formation of scale, sludge and cloth blinding compounds. The influence of chloride and fluoride levels on corrosion rates has also been mentioned and can be illustrated further by reference to results obtained from the testing of a high chloride phosphate rock which produces an acid of the following composition when processed by the Dihydrate route:

Table 4: Acid Compositions

<u>Component</u>	<u>Low Chloride Acid</u>	<u>High Chloride Acid</u>
P_2O_5	31.8	32.3
SO_4	1.8	2.06
SiO_2	0.78	0.15
F	1.52	0.41
Cl	0.006	0.75

Data from a low chloride rock are also included as a reference.

Samples of various steels were tested in the two acids for periods of about 1000 hours at a temperature of $80^\circ C$ to correspond with the Dihydrate process. The results (Table 5) indicate the large increase in corrosion rates due to the higher chloride level.

Table 5: Corrosion Rates

	<u>Corrosion Rate mm/year</u>	
	<u>Low Chloride Acid</u>	<u>High Chloride Acid</u>
316L	0.12	0.85
317	0.04	1.24
Uranus B6	0.03	0.18
Hastelloy C	0.11	0.12

The lower grade steels, 316L and 317, are more affected by the presence of chloride than the higher grade steels Uranus B6 and Hastelloy C. Fluoride also affects corrosion rates, but these effects are less serious than those due to chloride. There are also fewer examples of rocks which give high fluorine concentrations.

Conclusions and Future Trends

The increase in world consumption of phosphate rock will inevitably deplete the reserves of the well established phosphates which have known and manageable processing characteristics. This trend is already evident, and is affecting supplies of Florida, Morocco and Kola rocks, which together constitute the bulk of the world's exports.

An 'ideal' phosphate rock for phosphoric acid manufacture should have the following features:

- (a) High P_2O_5 to CaO ratio: to minimise sulphuric acid consumption and precipitated solids to P_2O_5 weight ratio.
- (b) Low organic matter: to minimise foaming, to avoid interference with filtration, crystal growth and recrystallisation of hemihydrate to gypsum.
- (c) Low carbonate content: to minimise foaming.
- (d) Low chloride content: to minimise corrosion.
- (e) An adequate SiO_2 to F ratio to avoid a large excess of fluoride in the phosphoric acid, thereby minimising corrosion and avoiding interference of crystal growth and the recrystallisation of hemihydrate to gypsum.
- (f) Low alkali metal content; to minimise fluorosilicate scaling.
- (g) Low levels of cationic impurities: to minimise sludge formation, loss of acid purity and loss of P_2O_5 water-solubility of phosphate intermediates.
- (h) Contain sufficient cationic impurities to produce rhombic-shaped dihydrate crystals. This is not necessary in hemihydrate processes.
- (i) High reactivity: to minimise unreacted rock P_2O_5 losses and grinding required.
- (j) Be relatively soft: to minimise power required for grinding.

Commercially available rocks have never met all of the above requirements, which vary in importance depending on the type of process used and the plant design employed. Clearly, the fertilizer industry must in the longer term be prepared to process rocks which are even less 'ideal'. Where phosphoric acid plants are located at the mine there will be a greater need to provide a 'tailor made' design to match the characteristics of the range of rock grades produced. Phosphoric acid manufacturers who purchase rock will have to accept lower standards or improve poor performance characteristics by modifying operating conditions and/or plant design and possibly consider the use of additives. Rock producers can also contribute, by giving attention to ways of reducing the levels of harmful impurities

which cause problems during phosphoric acid manufacture. Beneficiation treatments involving washing, density separations, flotation and calcination should be designed, not only to enrich phosphate, but also to minimise these impurities. In some cases it would be far preferable to produce a lower grade of rock in terms of P_2O_5 content if processing problems can be reduced.

To achieve real progress in the future the effects of impurities, particularly trace elements, on crystal habit and growth need to be understood and quantified. With this knowledge decisions can be taken at the rock beneficiation plant on the best purification route to aim for, in order to optimise processing performance. A better understanding of impurity effects will also allow phosphoric acid manufacturers to select phosphate rocks based on economic implications applied to their own plants. These implications need not necessarily be the same for different manufacturers.

Fisons have long recognised the need to obtain this basic knowledge. Some time ago a laboratory and pilot plant programme was designed to study the effects and interactions of impurities on crystal habit and growth. Sound experimental techniques have been developed which are acceptable models of full scale plant behaviour. Some progress has also been made using pure materials and commercial rocks on the effects of certain impurities. The work, however, has shown that great care must be exercised to avoid arriving at premature conclusions. Conflicting results on impurity effects are not difficult to obtain and these will not be fully understood until more is known about the selective and interactive effects of combined impurities.

Fisons also recognise the need to relate beneficiation techniques and rock compositions with processing behaviour in a phosphoric acid plant to allow the overall cost of beneficiation and fertilizer production to be optimised. This has led to collaboration on recent projects between Fisons and the Mineral Processing Division of Warren Spring Laboratory UK, in order to cover this broader field of operation. The significance of this collaboration will increase in the future as impurity effects are more fully understood and the increased use of lower grade rocks adversely influence the economies of phosphate fertilizer manufacture.

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