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PHOSPHATIC FERTILIZER PROBLEMS*

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* The views expressed in this paper are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO. This document is a translation of an unedited original.

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Introduction

It is quite clear that the odds against being able to resolve such a vast problem as this in a short report are very much against us. We can, however, hope to put before our readers some of our thoughts which, we hope, can show them new possibilities and so help them to find a solution to their problems.

It is not possible to envisage any complete separation between phosphate fertilizers and the other forms (N and K_2O) when we take into account the fact that the P_2O_5 component cannot be utilised on its own and that it is in fact only an essential link in the fertilization process. (Certain phosphate-based fertilizers such as DAP and MAP are, however, directly associated with nitrogen.)

It should also be noted that the study is designed to cover highly differentiated situations in the various countries, and that these are difficult to compare one with another. For example we may cite :

- Countries whose phosphatic fertilizers industries are directed either to the international markets or just to the domestic market;
- Countries whose geographical situation, with access to the sea and transport infrastructures, allows the easy entry of imported products or those countries which are land-locked;
- Countries which either enjoy, or lack, a major and solvent domestic market;
- Countries having major resources of raw materials of a quality meeting the standards of the fertilizer industry;
- Countries having raw materials resources of mediocre quality and quantity and which are more or less difficult to extract;
- Countries which subsidize their agriculture through fertlizers;
- Countries with a fully-defined agricultural policy (support for industrial crops, or the development of food crops, etc.);
- Countries possessing a technical environment which is thus able to master an industrial project;
- Countries concerned above all to minimize all forms of inputs;
- Countries with differing cultivation conditions (soils, climate, plants, etc.);
- etc.

It is thus possible to envisage an infinitude of combinations, and this alone illustrates the complexity of the problem to be resolved.

There is no general solution, and every case must be the subject of an individual study.

Deposits of phosphatic minerals are relatively widely distributed in Africa, and one may thus hope to be able to achieve fertilization using phosphates by utilising these resources.

THE PRINCIPAL PHOSPHATIC FERTILIZERS

These are very numerous. We list below the maximum number of such products, indicating with an asterisk (*) those products which are still in an experimental stage.

The products :

These may be grouped into four major families :

1 - Products containing completely attacked phosphates

- Simple superphosphates (H_2SO_4 attack)
- Enriched superphosphates (H_2SO_4 and H_3PO_4 attack)
- Triple superphosphates (H_3PO_4 attack)
- Nitrophosphates (HNO_3 attack)
- Sulpho-nitrophosphates (HNO_3 + H_2SO_4 attack)
- Sulpho-nitro-phosphophosphates (HNO_3 + H_2SO_4 + H_3PO_4 attack)
- Dicalcium phosphate (HCl attack)
- Phosphoric and superphosphoric acids
- Salts of the above acids (DAP, MAP, etc.)
- etc.

2 - Phosphatic products obtained by means of thermal processes

- Alumino-calcium phosphate (Phospal)
- Rhenania phosphate
- Fused phosphates (China, Canada, Brazil)
- Basic slags.

3 - Products containing phosphate rocks

- Fertilizers for "Direct application", containing essentially ground phosphate as the phosphatic product
- *- Combinations of ground phosphates and organic materials
- Combinations of ground phosphates and sulphur (Bio-super)
- *- Combinations of ground phosphates + sulphur + bacteria (Polish process)
- *- Combinations of ground phosphates + micro-organisms (India).

4 - Products containing partially-attacked phosphates

- Attack using phosphoric acid
- Attack using sulphuric acid
- Attack using nitric acid
- Attack using a mixture of the above acids
- Attack using the above acids in the presence of salts
- *- Attack using nitrous oxides in the presence of organic materials (Humifert process)
- *- Attack using the organic acids resulting from the simultaneous composting of organic materials
- *- Attack using SO_3 (Polish process).

It may be seen that the products are very numerous and very diverse, so that the possibilities opened up are also very extensive.

Whilst the products in family 1 are well known, since they form the traditional range of fertilizers, the same does not apply to the other families, and it is necessary therefore to provide at least a minimum of supplementary information.

Products in family 2

- Phospal is a special product obtained by the thermal treatment of an alumino-calcium phosphate mineral from Senegal: P_2O_5 = 30% to 34%. It is an interesting product for fertilizing neutral or alkaline soils.
- Phosphates which have been broken down by the thermal treatment of phosphate minerals in an alkaline environment and in the presence of silica. Their production requires large amounts of energy.
- Fused phosphates obtained by the high-temperature treatment of mixtures of phosphatic minerals and fluxes such as serpentinite. These products can be produced at semi-artisan level, but they do require large amounts of energy. They are very widely used in China (magnesium phosphate). Low grade phosphates can be utilised. These products have neutralising properties. P_2O_5 = 15% to 20%.
- Slags, which are in fact a by-product of the dephosphoration of steel. P_2O_5 = 12% to 18%. The product contains CaO and MgO and hence has neutralising properties; it also contains many trace elements.

Products in family 3

This less widely-used family consists of more specialised products. It is in fact possible to utilise phosphatic minerals directly as fertilizers.

The phosphate contained in this type of fertilizer has not therefore undergone any chemical treatment, and is thus in its original form; it is, however, generally ground.

In this type of product the transfer of the P_2O_5 to the soil and to the plant is very much slower than with the other forms of fertilizers, and a number of precautions must be taken if the result is not to be failure.

The utilisation of this type of fertilizer meets certain constraints :

- The acidity of the soil (pH $<$ 5.5).
- The climatic conditions (rainfall and temperature).
- The efficacy varies with the plant concerned.
- The general need for fine grinding (90% $<$ 63 microns).
- The quality of the phosphate (not all phosphates can be used). Very careful analyses have to be carried out to judge the quality of the phosphate :
  - Its solubility in various reagents (formic and citric acids, etc.);
  - The kinetics of the P_2O_5 extraction in columns;
  - The porosity of the phosphate (Hg or BET absorption);
  - The crystallographic parameters;
  - Mineralogical analyses;
  - Confirmatory agronomic trials (Measurements on the P_2O_5 extracted by the plant).

Once these precautions have been taken it is possible to obtain in this way products which are extremely efficacious and very economical. (The African continent possesses a number of phosphates which may be used : Tunisia, Algeria, Morocco, Senegal (Matam), Mali (Tilemsi), etc.

This type of product has often been criticised on the grounds of low concentration, making transport costly. This comment calls for some correction since these phosphates generally have an improving effect on the often acid soils of Africa, by reason of their contribution of CaO and MgO. A very simple calculation leads to an interesting comparison.

Quantity		P_2O_5	CaO ⟶	$CaCO_3$	Total $P_2O_5 + CaCO_3$
1.0 tonnes super triple	=	0.450	0.200	0.400	0.850
1.6 tonnes phosphate	=	0.450	0.720	1.440	1.890

Amount of $P_2O_5 + CaCO_3$ from 1 tonne super triple = 0.850
Amount of $P_2O_5 + CaCO_3$ from 1 tonne phosphate = 1.180

The criteria for selecting the phosphates differ considerably from those normally employed, and make it possible to utilise phosphates normally regarded as of no interest and which are thus cheaper.

The other products in this family reflect the desire to increase the availability of the P_2O_5 in the phosphate by :

- Solubilization taking place in the soil effected by various means such as :
  The natural oxidation of sulphur to produce SO_2 and then SO_3;
  The accelerated oxidation of sulphur by bacteria;
  Direct solubilization using bacteria or moulds.

The authors claim to be able to utilise a wide choice of phosphates (such as indurated phosphates).

Products in family 4

This family also consist of fairly special products which are, in fact, intermediates between direct application products and the conventional products which are regarded as being totally and immediately soluble.

It has already been seen that in the case of the direct application of phosphates one of the factors limiting the use of this technique was the relatively slow rate at which the P_2O_5 was made available to the plant, so that the selection of directly utilisable phosphates had to be rigorous, eliminating a large number of phosphates.

The need was soon felt, therefore, to seek to improve the mobility of the P_2O_5 by partial attack on the phosphate so as to improve :

- The agronomic qualities of the phosphate;
- The range of utilisable phosphates;
- The fields of application (less acid soils).

Here again a number of errors were committed and, contrary to what had been hoped, the products obtained by partial attack were found to be less agronomically effective than the initial phosphate. A technique which, at the start, had seemed simple was in fact found to be much more complicated.

It was very soon seen that it was necessary to maintain total control of the reaction conditions so as to prevent the formation of certain intermediate chemical compounds which appeared during the attack process; once these conditions were fulfilled the technique involved became relatively simple.

(See the Annex relating to partial attack processes.)

It was also found that these products are not just a combination of attacked and non-attacked products, but their properties make them quite individual products, particularly where their agronomic properties are concerned.

Concluding, therefore, it is possible by means of partial attack on phosphates -

- To obtain products which are agronomically interesting because of their :
  - Agronomic efficacy,
  - Improving effect, by supplying Ca and Mg,
  - The 'starter' effect from the attacked part,
  - The long-term release of the P_2O_5,
  - The lower blocking of the P_2O_5 in certain soils,
  - etc.
- To obtain products which are of economic interest because of :
  - Reductions in the quantity of the attacking agent. From 20% to 30% is generally sufficient to obtain effective products (acids are generally expensive),
  - An extension of the range of phosphates which can be used, with the possibility of using phosphates generally regarded as of little interest (reactivity, percentages of R_2O_3 and MgO),
  - A simplification of the processing installations (semi-artisan techniques),
  - etc.

Nevertheless the advisability of implementing this technique is linked with a number of parameters which need to be studied case by case, since the final aim of any operation is to reduce the cost of fertilization rather than the production of a cheap fertilizer.

Commercial forms of fertilizers

The products are marketed in various forms :

- Fine powders, less than 200 microns, as in the case of ground phosphates, not generally liked by users because of the dust;
- Coarse powders, up to 2 mm;
- Semi-granulated, 6-7 mm (Run of Pile);
- Granulated, spherical products either 1.5-4 mm or 2-5 mm, easy to store and to handle, low uptake in bulk, little dust, etc.;
- Compressed or compacted, a less spherical product with a broken appearance, more dusty because of the abrasion of the edges;
- For completeness there are liquids, suspension, slurries, etc., but these forms are not used in Africa.

The normal packaging is in 50 kg woven polypropylene bags with an inner sealed and sewn polyethylene bag. Little use is made of bulk storage.

PRODUCTION PROBLEMS

The basic raw materials

The production of fertilizers requires a limited number of basic raw materials as follows :

- Phosphatic minerals.
- Energy-providing materials (coal, oil, gas, electricity, lignites, etc.).
- Sulphur-containing minerals (metal sulphides, gypsum, sulphur).
- Potassium-containing minerals (sylvinite, carnallite, etc.).
- Magnesium-containing minerals (serpentinite, dolomite, giobertite, etc.).

These products can participate more or less directly in the production of phosphatic fertilizers.

The principal production processes are shown in the following pages, which illustrate the principal combinations which can be envisaged.

The intermediate raw materials

These are the products which are manufactured more or less directly from the basic products and which are major intermediates in the production of fertilizers.

They can be easily bought as raw materials for the converting industries, and are generally manufactured in the major chemical complexes.

They include :

- Sulphuric, phosphoric and nitric acids (it should be noted that because of the concentration needed in fertilizers it is not possible to transport nitric acid);
- Ammonia (a concentrated product containing 82% nitrogen; difficult to transport and to store);
- Urea, ammonium nitrate, DAP, MAP and Super 45, which are also regarded as finished products.

The supplementary raw materials

These are essential in fertilizers, and may be associated with the phosphatic products indicated above. They include :

- Ammonium sulphate,
- Ammonium bicarbonate,
- Potassium nitrate,
- Calcium nitrate,
- Potassium chloride,
- Potassium sulphate,
- Potassium-magnesium sulphate
- Trace elements,
- Magnesium oxide and salts,
- etc.

The basic phosphatic fertilizers must be as compatible as possible with these substances.

The criteria for selecting raw materials

As has already been seen in the previous sections the choice of the raw materials generally depends on their subsequent utilisation. We will attempt to identify the criteria to be adopted for the principal products.

I - The phosphate

This is the fundamental raw material.

I-1 Direct application

- The solubility of the phosphate in formic or citric acids.
- The dynamic solubility.
- The porosity of the phosphate and its specific surface area.
- Certain crystallographic and mineralogical parameters.

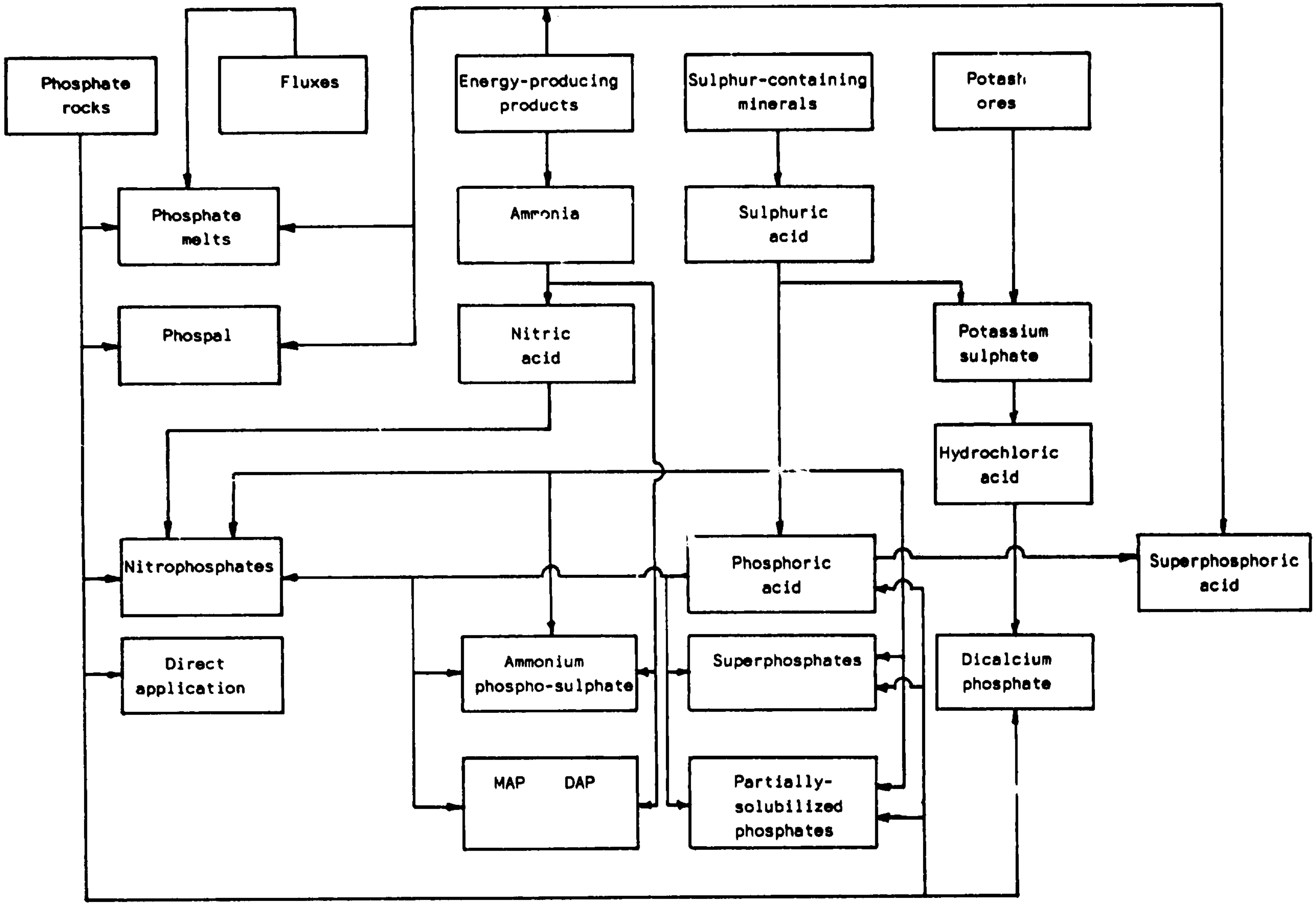

Phosphate rocks
Fluxes
Energy-producing products
Sulphur-containing minerals
Potash ores
Phosphate melts
Ammonia
Sulphuric acid
Phospal
Nitric acid
Potassium sulphate
Hydrochloric acid
Nitrophosphates
Phosphoric acid
Superphosphoric acid
Direct application
Ammonium phospho-sulphate
Superphosphates
Dicalcium phosphate
MAP DAP
Partially-solubilized phosphates

FIGURE 1

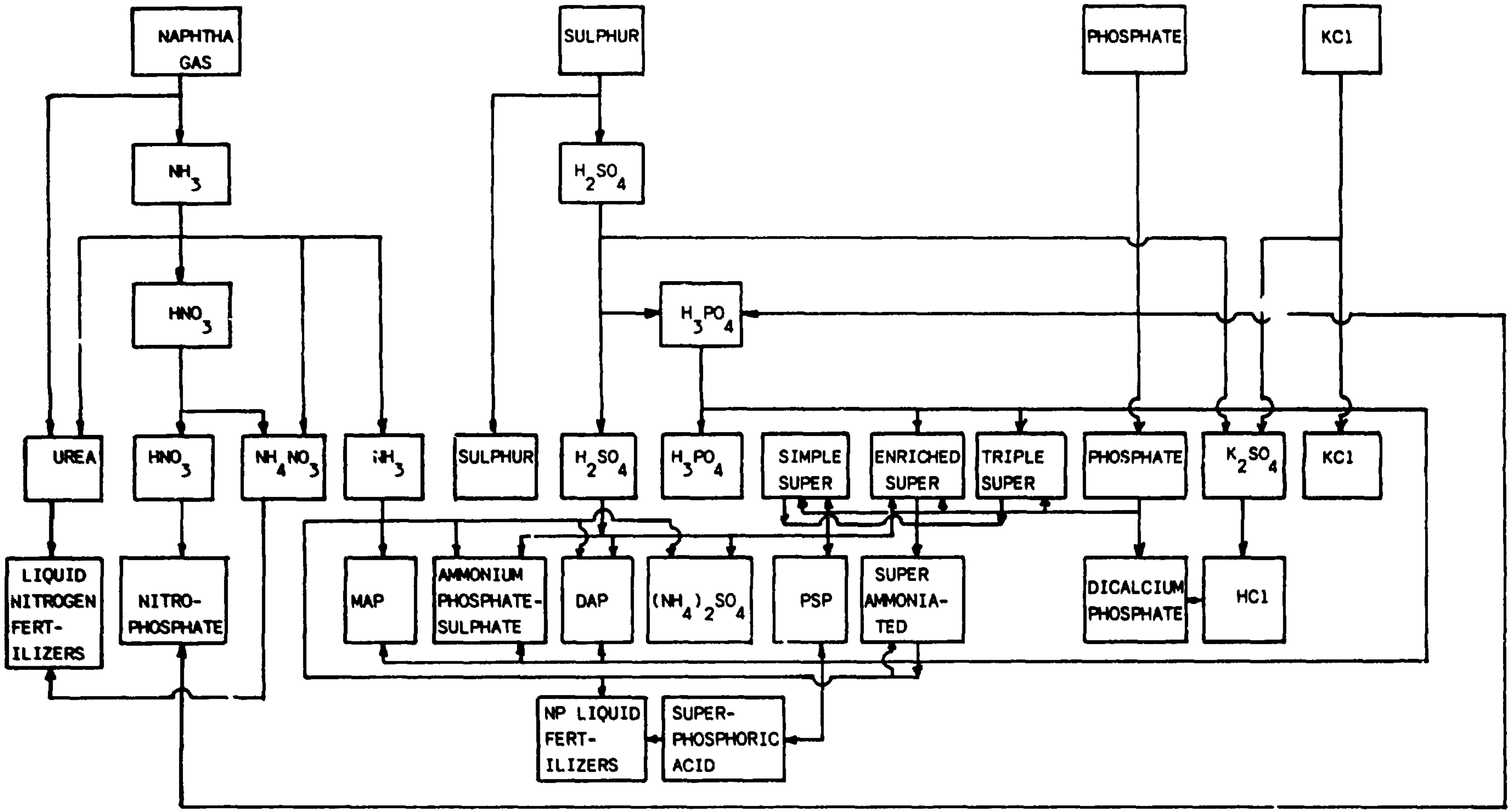


Figure 2 The principal fertilizer routes

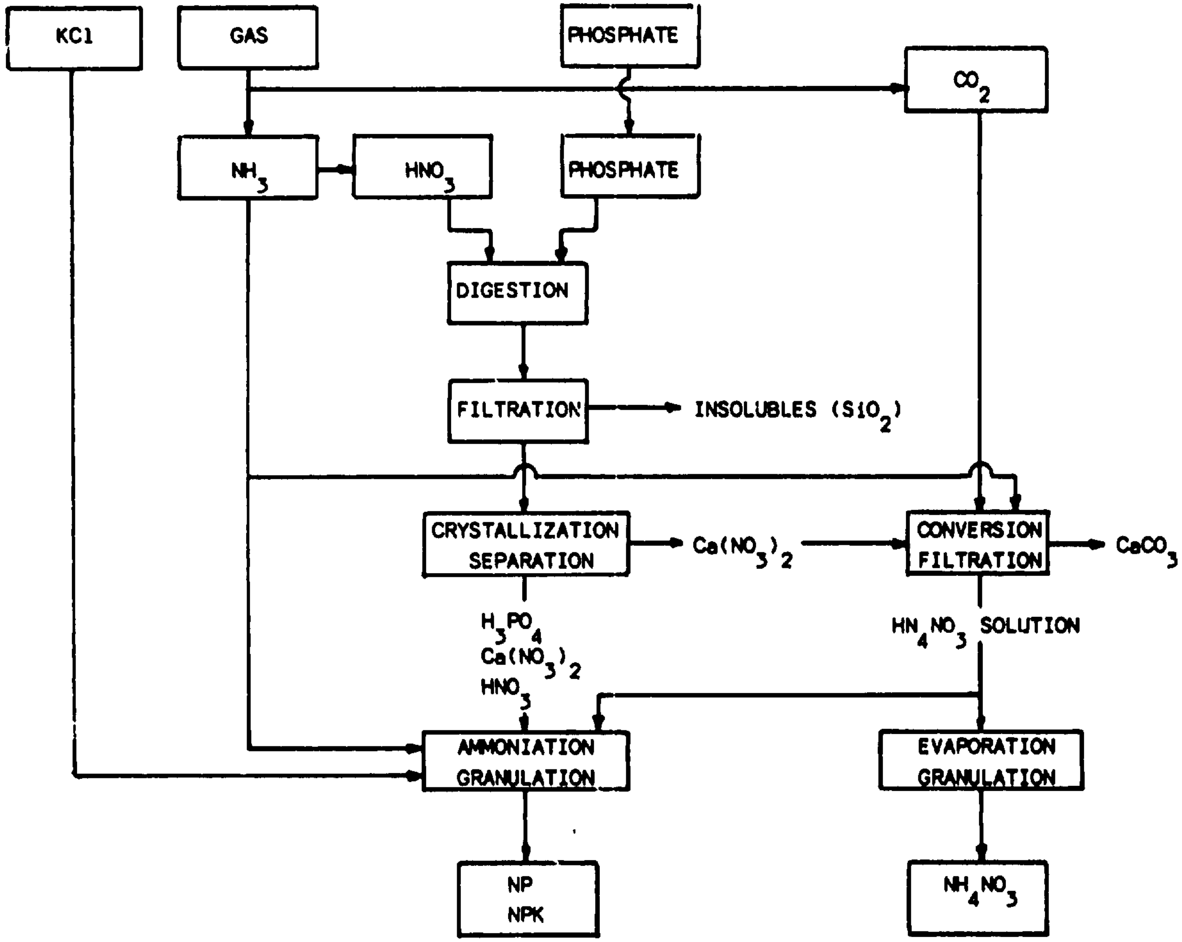


Figure 3 The nitrophosphates

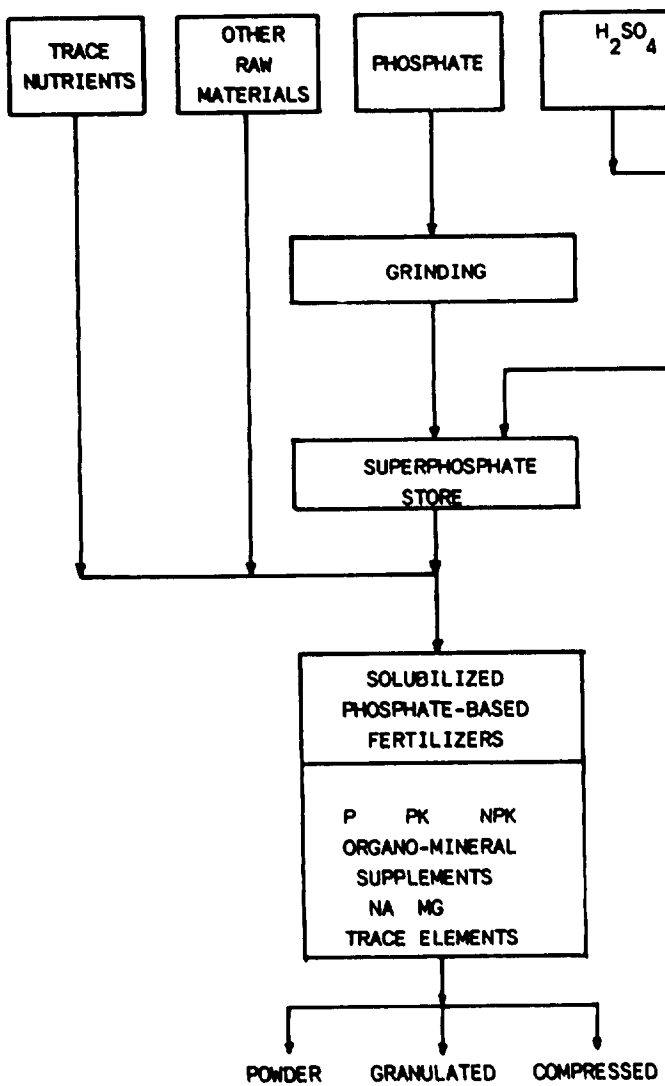


Figure 4 The so-called totally sulubilized phosphate-based fertilizers

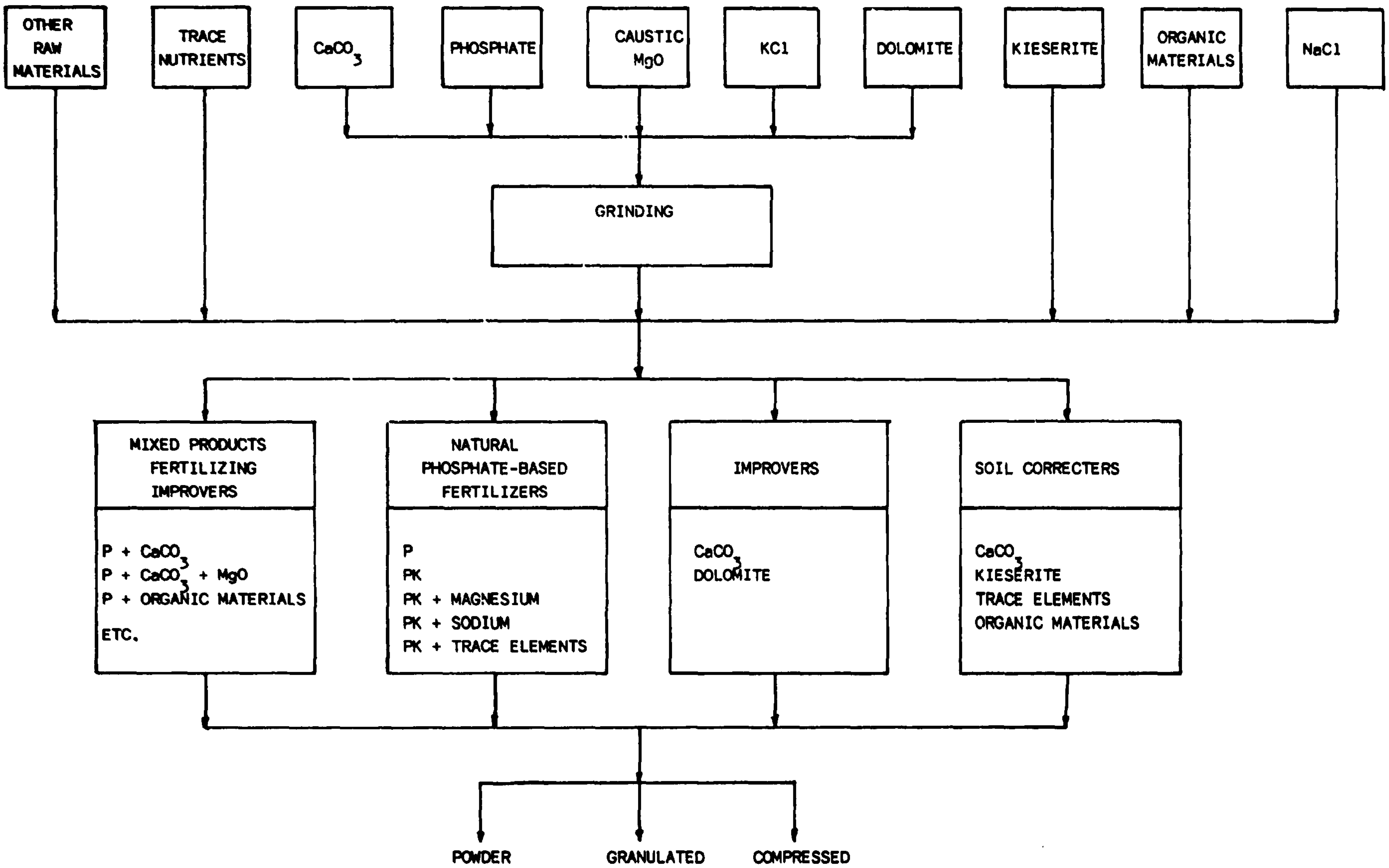


Figure 5 Fertilizers based on natural phosphates

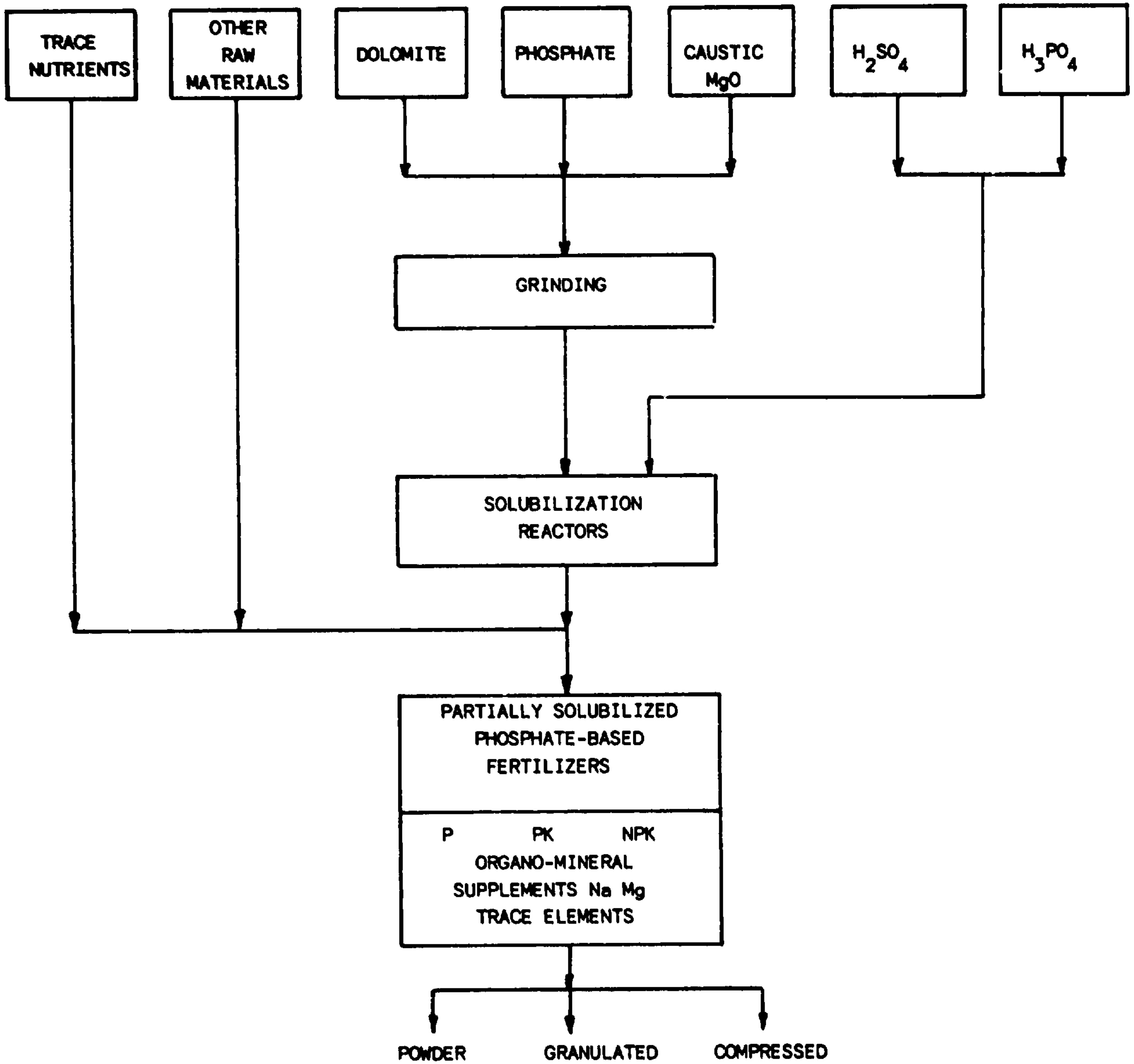


Figure 6 Partially solubilized phosphate-based fertilizers

Fig. 7 : List of the basic or ancillary raw materials used in the production of fertilizers

	N	P_2O_5	K_2O	Na_2O	MgO	S	Trace elmts	Organic matter
Phosphate		x						
Partially solubilised phosphate		x				x		
Simple super		x				x		
Triple super		x						
Alumino-calcium phosphate		x						
Basic slags		x					x	
Dicalcium phosphate		x						
Potassium phosphate		x	x					
MAP	x	x						
DAP	x	x						
Ammonium sulphate	x					x		
Ammonium carbonate	x							
Ammonium nitrate	x							
Ammonium chloride	x							
Potassium nitrate	x		x					
Cyanamide	x							
Urea	x							
Sulphur-containing urea	x					x		
Ammonium sulpho-nitrate	x					x		
Calcium nitrate	x							
NH_3	x							
Sulphomag			x		x	x		
Potassium sulphate			x			x		
Potassium chloride			x					
Lysine production residues	x		x			x		x
Mixed sodium/potassium chloride			x	x				
Sodium chloride				x				
Sodium phosphate		x		x				
Calcium-magnesium phosphate		x			x			
Sulphur						x		
Kieserite					x	x		
Magnesium oxide					x			
Dolomite					x			
Magnesium carbonate					x			
Colemanite							x	
Sodium borate				x			x	
Marl					x		x	
Isobutylene di-urea	x							
Fermentation washes	x		x			x		x
Molasses								x
Ground hoof and horn	x							x
Dried leather offcuts	x							x
Dried agricultural waste	x							x
Poultry droppings	x	x	x		x			x
$CuSO_4$ - Cu_2O							x	
$ZnSO_4$ - ZnO							x	
$MnSO_4$ - MnO etc.							x	

- The P_2O_5 concentration of the phosphate, which is determined solely by the tranrport problems, and which may be low (15% to 25%).
- If possible a low free silica content so as to avoid major maintenance costs on the grinders.
- The presence of magnesium is, on the contrary, an advantage.

It may be pointed out that if the characteristics of the phosphate meet the utilisation criteria in regard to the mobility of the P_2O_5 then the other constraints are relatively minor, so that it is generally possible to utilise the phosphate directly without enrichment treatment, or at least after limited treatment.

I-2 The production of phosphoric acid

The production problems here are much more complicated, and pose much greater constraints.

- The maximum P_2O_5 concentration is required, with the highest possible P_2O_5/CaO ratio so as to limit the acid usage.
- The minimum Al_2O_3, Fe_2O_3 and MgO percentages, to reduce the consumption of acid and to reduce the formation of troublesome compounds.
- The minimum chlorides percentage and SiO_2/F ratio so as to limit corrosion.
- The minimum organic materials percentage to prevent foam formation and to limit the usage of anti-foaming additives.
- The minimum cadmium percentage (international legislation).
- The minimum free silica, to limit abrasion.
- The reactivity of the phosphates, to limit -
    - capital investments in grinding and the reaction vessel,
    - the consumption of energy during grinding and for stirring in the reaction vessel.
- The crystal form of the gypsum (filtration).
- etc.

Enrichment and purification treatments of the phosphatic mineral, which are sometimes very costly, are therefore generally necessary.

The constraints are thus considerable and limit the grades of phosphate which are economically utilisable.

In the production of phosphoric acid it is of interest to examine the following parameters, all related to the production of 1 tonne of P_2O_5 as phosphoric acid -

- The quantity of phosphate needed.
- The quantity of sulphur needed.
- The quantity of anti-foams needed.
- The quantity of energy.
- The cost of maintenance caused by corrosion and abrasion.

These items account for a large part of the cost price of the phosphoric acid.

I-3 Nitrophosphates

The constraints here are somewhat less serious than those indicated above, but the following can be cited -

- Maximum P_2O_5/CaO ratio to limit acid consumption.
- Carbonate content not too high, and
- Minimum organic materials percentage, both to reduce foaming problems.

By contrast the level of capital investments and the complexity of the processes is greater.

I-4 Superphosphates

The constraints here are similar to those applying to phosphoric acid, with however slightly more latitude.

- Greater tolerances in regard to the Al_2O_3, Fe_2O_3 and MgO levels.
- Carbonate content of value (expansion of the superphosphate).
- The phosphate being generally ground to a finer size means that its hardness and the free silica content has to be watched more closely.

I-5 Partial attacks

In the special case of partial attack the constraints on the use of the phosphate are generally very minor, since -

- the levels of attack on the phosphate are obviously lower than in the case of total solubilization, so that troublesome reactions can be better controlled,
- the treatments used can be adapted to suit the grade of phosphate being used.

It is possible to use directly those grades of phosphate which are classified as non-usable because of their concentrations of P_2O_5, Al_2O_3, Fe_2O_3 and MgO, and without any enrichment treatment.

Under these conditions the range of acceptable phosphates is very large. In fact the problem which is posed is :

How to treat the available phosphate ?

II - The phosphoric acid

This product is an important intermediate in the manufacture of fertilizers and is often involved as a raw material in the production of many phosphatic compounds.

The quality criteria are :

- A P_2O_5 content exceeding 50%.
- The level of materials in suspension, to limit deposition and losses during storage and handling.
- The minimal reprecipitation of salts, to limit deposits and scaling.
- The minimum percentage of salts in solution. Since this product is used as an acid reaction agent the maximum amount of the P_2O_5 present should be in the form of phosphoric acid.

This product is costly to transport and to store, since it requires special equipment, whilst losses have to be expected during the storage and transport operations.

III - DAP, MAP and Superphosphates

These products, which are widely available on the international market, are the subject of intense competition between the different producers, and are hence not very remunerative. This is why the nitrogen content of MAP and DAP is generally of little interest.

These products do however have the advantage of being very concentrated in respect of their fertilizing units, and so can accept the cost of transport over longer distances.

THE PRODUCTION STRATEGIES

One can distinguish between three production strategies :

1 - A strategy based on the production of fertilizers intended for bulk export, such as :

- More or less enriched phosphatic minerals.
- Phosphoric acid.
- MAP and DAP.
- Triple superphosphate.
- NP and NPK fertilizers, as concentrated as possible.

This strategy demands a high level of industrialization in order to produce, in large quantities, a limited range of standardized products. This strategy is suited to the major producers located at major phosphatic minerals sites. (Production of basic phosphatic fertilizers.)

2 - An intermediate strategy based on supplying nearby markets, national and neighbouring: this is suited to producers of medium size. Here the range of finished products is necessarily wider in order to meet the local conditions. The operating conditions here are much more difficult to control and to optimise.

The major problem in this strategy relates to the possibilities of obtaining raw materials at a good price, since any scale economies do not operate in this case.

3 - A national strategy, based on identifying an economic system of fertilization which is more lightweight, more rustic and nearer to the final user, the peasant farmer.

It needs to be capable of utilising to the maximum the local resources, even if these are modest, supplemented by the generally available raw materials which can be obtained at good prices on the international markets.

Adaptability and flexibility should be its principal advantages.

The choice of the production strategy is the essential starting point for consideration of the implementation of any phosphatic fertilizers production project.

OPERATIONAL CONSIDERATIONS

As can be seen from the simplified scheme for the production of the principal phosphatic fertilizers the production of these in the traditional system involves a number of production units which are integrated vertically, leading to some complexity in operation.

These units are not only interdependent in regard to their products but also in regard to energy transfers.

Furthermore these production units can only operate continuously; any shutdowns must be for technical reasons and for limited periods of time, since starting up again is very costly in terms of energy and maintenance (reheating of the circuits, slow operation, corrosion on shutting down, etc.).

This leads to some rigidity in the process.

The important points to be taken into consideration are :

- The technical nature of the production units, demanding operators who are not only competent but also very painstaking and highly motivated (constantly seeking the optimal operational possibilities of the unit).

- The high level of capital investments (considerable scale economies, high levels of instrumentation of the units so as to be able constantly to optimize productivity and to achieve a high level of operational safety).

- The need for rigorous management of energy, demanding as a consequence the highest level of utilisation in the units.

Energy recovery takes place by successive stages. A reduction in the level of utilisation in one unit of a few percentage points can therefore have catastrophic results on the final energy balance sheet.

- Optimization of the performance of a unit is rarely achieved at start up. It is normal for it to be reached after several years of work on development and improvement. Perfecting the units must be the constant concern of the operator.

- Since the techniques evolve very rapidly they must be constantly followed up and, if necessary, adapted to the production unit (development budget).

- Management of production is very difficult and requires the steady flow of the products manufactured if one does not want to have to maintain large stocks or to have to shut down the production line sections.

- Management and maintenance must both be above criticism, establishing a good balance between preventive maintenance and breakdown operations; this is not easy to achieve if an industrial fabric does not already exist in the environment of the plant (problems with spares and exceptional support in the case of serious breakdowns).

- The search for simple technical solutions is a primary concern under these conditions. At the time of making the capital investments priority must be given to robust and, in the final resort, artisan-standard installations.

- The skills of the operators and supervisors in charge of the continuous processes must be reasonably high, since they are responsible, for 24 hours every day, for sophisticated and expensive units. They must therefore be able to withstand a fairly stressful situation because of the heavy responsibilities which they have to assume and the work load (shift work).

- Local recruitment of such personnel is not easy, so it is often necessary to call on expatriates, so considerably increasing the wage bill. A policy of training must be implemented.

- It is therefore necessary to have concern for the simplicity of operation.

THE PROBLEMS OF THE TRADITIONAL INDUSTRY

The commissioning of fertilizer production units intended for bulk export, or even to serve neighbouring markets (Strategies 1 and 2) is a very difficult operation to carry out.

It should only be envisaged if an exceptionally favourable series of circumstances can be established.

Competition is pitiless, and it is essential to be able to compete on equal terms with the competitors, making it essential to reach at least an industrialized level of performance.

It is necessary also to remember that the competitors often price their products on the basis of policies which sometimes have nothing in common with the normal criteria of profitability, operating dumping prices for a variety of reasons :

- The desire to ensure control of the markets in the longer or shorter term.
- The need to acquire foreign currency at any price.
- The need to discover markets so as to ensure an acceptable level of utilisation of their units (marginal tonnages).
- The protection of privileged markets.
- The need to reduce stocks,
- etc.

Before launching out into this type of operation it is necessary to examine carefully :

- those projects which are under study or in course of construction,
- any projects involving reconversion and restructuring.

It is also advisable to examine carefully, and in advance, those advantages which are already possessed and which would make it possible to withstand such a situation.

The important parameters to be taken into account are :

- Significant resources of good quality phosphate which can be easily mined.
- Energy resources (gas, oil, coal and electricity) available in quantity and supplying cheap energy.
- Resources of sulphur-containing products which could be used to manufacture sulphuric acid.
- A minimum level of control of the market for the finished products or of supplies of raw materials, linked for example with the influence one has on the world market, a particularly favourable geographical situation or privileged agreements.

- The total mastery of the production operations and the maintenance of the units, ensuring an advantageous cost price for the products.

In conclusion :

It seems to us to be particularly hazardous to envisage an operation of international scope unless one can master at least three of the parameters indicated above.

(The examples of such operations undertaken recently show us quite clearly the magnitude of the risks involved.)

The world fertilizer industry is at the present time in a state of major crisis; this is the more serious since it does not result from an excess of capacity over the needs of the consumers but because the price of these fertilizers, as delivered to the fields, cannot be afforded by the potential customers.

Nor must it be forgotten that a profound imbalance exists in the world with agricultural production largely in excess in many countries where it is, at the same time, highly subsidized.

This situation could change rapidly, and this could be catastrophic for a number of Developing Countries which have not promoted their own agricultural development.

Many serious questions must therefore be confronted.

The cost of using fertilizers must be reduced for the user.

Since this in-depth questioning is necessary we must go right to the roots of the problem and ask ourselves a number of questions :

- Is it possible to reduce the price of the traditional fertilizers, and if so, how ?
- Are these products totally suited to crop-growing conditions in Africa, and can they be recommended in all cases ?
- Without denying the need to use traditional fertilizers or their efficacy are there no alternative products which are of greater interest and more economically valid in certain situations ?
- What is the real cost of using fertilizers if one integrates the cost of the treatments necessary to maintain good fertility in the soil and to achieve an increase in agricultural production ?
- Are the logistics and distribution really suitable, or could not both of them be improved ?
- Is it not possible to favour a local mini-industry which would be capable of satisfying the real local needs, and which could perform a number of simple operations such as :
  - Formulating fertilizers;
  - Bagging them;
  - Utilizing local resources of raw materials,

and which would simply operate as a converter, using those widely distributed products from the major producers, and which are therefore available at interesting prices ? (Thus exploiting the incoherences of the world market.)

- Could not the system envisaged have as its ultimate aim that of being supplementary to the traditional system ?

CONSIDERATIONS RELATING TO A NATIONAL SYSTEM

As might be expected the approach needs to be totally different and requires the identification of original solutions.

Since the final aim is to provide fertilizers at the most economical price to the user action must be taken at every stage of the fertilizers circuit.

To this end the following operations must be carried out :

- Produce an accurate inventory of local resources of raw materials which could be used (grades, quantities, location, accessibility and estimates of production cos .
- Produce an accurate inventory of the real needs of the user under real crop-growing conditions (plants, soils and the climate), not only for the fertilizers but also for other products such as soil improvers, pesticides and trace elements.
- Produce an inventory of existing uses of these same products (grades of products used, quantities, timetable of use, precise location of the areas of use, etc.).
- Produce an inventory of fertilizing products which could be supplied economically.
- Produce a complete inventory of the logistic cost along the entire supply and distribution network so as to identify bottlenecks and anomalies (bulk transport and handling of fertilizers is relatively difficult to achieve in Africa, and the costs are very high). In our opinion there is a major logistics problem, disrupting not only the distribution of fertilizers but also the collection of finished agricultural produce (means of transport, infrastructures, etc.).
- Determine objectively the real resources of the user in order to fix an acceptable price ceiling for fertilizers.
- Decide how the farmer is to be aided (subsidies on fertilizers or products, introduction of new cash crops, assistance in the purchasing of fertilizers, etc.).
- Determine which structures are to be responsible for this development at country and user levels.
- Determine which products could be produced economically.
- Determine which system would allow the creation of value added at a high local level, in this way limiting inputs and saving currency.

- Determine the technical means to be implemented to manufacture these products economically, limiting the capital investments required and hence also the risks (this could involve the revamping of a unit).
- Identify the entrepreneur to be responsible for the complete management of the project. This point seems to us to be particularly important, since in our opinion nothing of value could be achieved without a competent and responsible coordinator and driving force: the ongoing work of optimising costs at each stage will be a necessity for the success of such a project. He must have all the necessary powers.
- Define a coherent and clearly set-out national policy for the use of fertilizers (draconian control of imports, clear definition of the utilization of additives in fertilizers, etc.).
- Seek cooperation between countries to share resources (port facilities, shared storage of raw materials, logistic resources, customized production, etc.).

As may be seen this is very far from a purely technical approach. The intervention of a large and multi-disciplinary team is necessary, and within this team the final user must be strongly represented. His real problems must form the starting point for all considerations on the subject.

This approach, which would seem to be logical, is not unfortunately always followed. One can see the construction of national projects which are limited to the building of "shop-window" factories, overlooking the fact that production cannot exist unless one can sell the products which are being manufactured.

All this seems to be complicated, but studies carried out in a number of countries have shown us that the cost of fertilizer usage could be reduced if these parameters were examined with care and, above all, together.

We have been able to ascertain that :

- The logistic cost is generally much greater than the production cost.
- The road infrastructure often does not permit the normal flow of products. (This is a very important point, since the costs resulting from rectification of the situation cannot be met by any one fertilizer project.)
- The economies achieved by a good choice or good purchasing of raw materials is sometimes even greater than the production cost.
- Independence in buying is absolutely essential. (Flexibility in the use of raw materials.)
- The farmer recognizes the efficacy of his fertilizers, but he is also sensitive to the appearance of the product; he is mistrustful of powdered products which look too much like 'sand'.

Mistakes must not therefore be made in regard to these priority points.

Unfortunately we have been able to identify, in the course of these same studies, a number of serious anomalies :

- Unsuitable formulae with, as a consequence, wasted fertilizers, such as the use of sophisticated fertilizers intended for cotton being used on cereals, the addition of K_2O to soils sufficiently provided with this element, etc.

- Aberrant logistical costs (ad hoc transport, failure to utilize the potential for return loads, loss of products during transport, etc.).

- Excessively high storage costs (loss of products, long storage times linked with uncertainties regarding supplies, etc.).
- Lack of storage capacity and storage under precarious conditions, making it necessary to buy products at unfavourable times).
- Shortages of supplies at the point of use (favourable climatic conditions creating unexpected demands for fertilizers which cannot be met).
- Or, on the contrary, returns to stock result in product losses (deterioration of the products from one campaign to the next).

The problem is that there is often no management at all, hence losses are considerable throughout the entire length of the network.

An overall approach is neccessary.

By way of illustrating this point Figure 8 on the following page makes it easy to appreciate the need for this type of recommendation, showing the importance of simplifying the circuits and the relative weights of the various operations.

SIMPLIFIED SCHEME FOR STUDYING A LOCAL PRODUCTION PROJECT

This approach to the problem is thus very different from the traditional approach, since it must be defined from the starting point of optimising the following points which are, in reality, interlinked and hence are redundant :

1 - The real cultivation needs as determined by agronomists.
Requirements for fertilizing components :
N, P_2O_5, K_2O, CaO, MgO, S, trace elements.
Ceiling prices for fertilizers.
Timetable of usage, etc.

2 - Local resources of raw materials for fertilizers as determined by geologists, mineralogists and miners.

3 - Possibilities of obtaining supplies of supplementary raw materials at the lowest cost, as determined by specialist buyers.

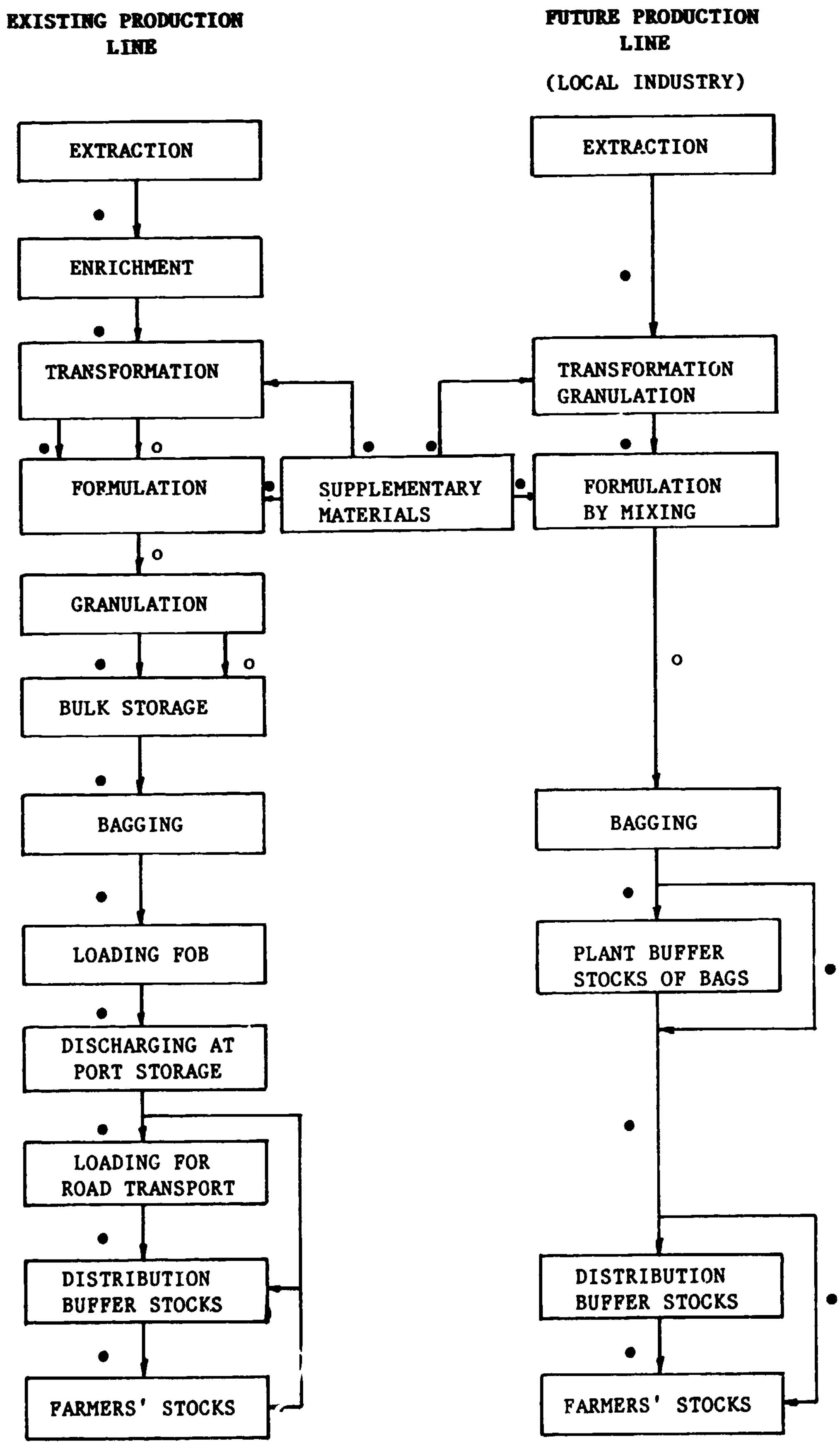
4 - Studies on logistic and distribution costs, carried out by a logistician.

5 - Determination of the products which can be manufactured and of suitable production techniques, carried out by specialists in the production of fertilizers.

6 - Financial and accounting studies (financing of investments, stocks, establishing forecast cost prices, elasticity tests, studies on levels of independence, etc.).

7 - Macro-economic studies to establish a policy for fertilizer usage to be implemented in the country, carried out by an economist.

One sees here again the concept of team work involving persons with multiple competences and viewpoints, integrated into an optimization unit which must be motivated by an entrepreneur who is completely objective and free from any constraints.



● Load breakdown or transport operation

o No load breakdown or transport

The imagination and creativity of this team are of primary importance, since it is necessary to implement new techniques or to harmonize a number of techniques which are already known, integrating them all into a coherent system.

It is necessary to accept some risk, this being the consequence of the necessary innovations. It is essential to leave the well-trodden paths; every day the traditional systems demonstrate to us their impotence in solving the problem without the support of major subsidies.

These studies must be carried out for each project and are always specific; however a 'package' could be defined which would speed the work up by systematizing the studies.

The simplified scheme which is set out on the following page makes it possible to illustrate the complexity of the system, linked with the interdependence of the factors involved.

CONCLUSIONS

On arriving at the end of this report the reader may be surprised to find only questions and few precise answers. Nevertheless it is possible to identify some underlying ideas, summarized as follows :

1 - There will certainly be no universal solutions.

2 - The use of fertilizers being essential they must therefore be made available to the farmer, since the development of agriculture is a vital necessity. We have now arrived at a point where the very fertility of the soils is placed in jeopardy.

3 - The cost of fertilizers is too high, considering the resources of the farmer; the known methods do not allow any reduction in their cost (with the situation of the manufacturers being far from flourishing they are more likely to seek price increases).

4 - The economies of African countries force them to limit inputs because of a lack of foreign currency, itself the result of falling prices for agricultural products and raw materials.

5 - Major innovations, or at least major changes in habits, are essential.

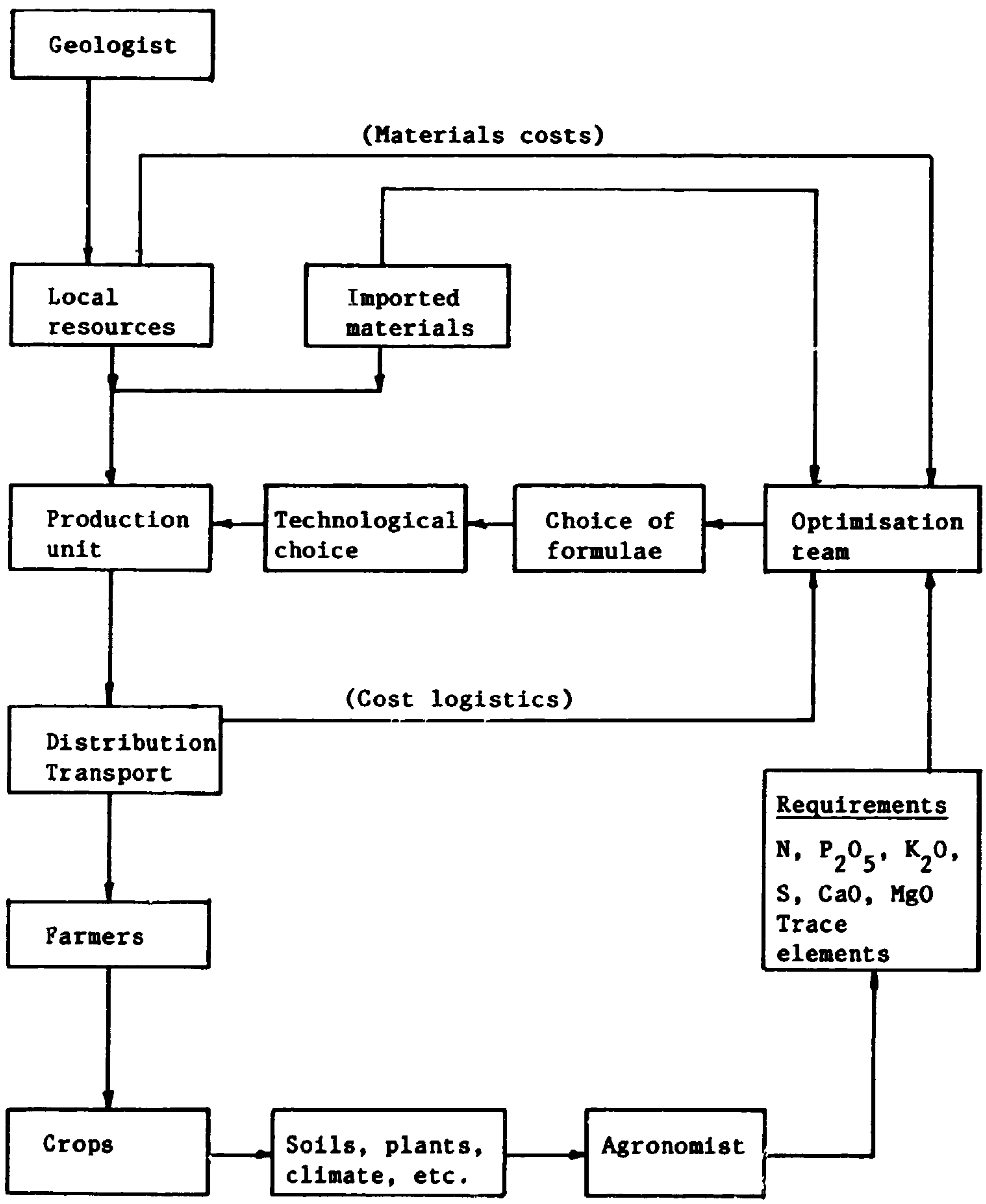
6 - Three points are, in our opinion, of primary importance :

- Firstly the need to structure agricultural development (agricultural cooperatives ?), and to find 'managers' for this policy:
- The need to form an operational unit for technical development (committees of experts and savants) to work very closely with the structure described above:
- The need for states to cooperate in concerted operations.

7 - The technical problems do not present any insurmountable difficulties: what is above all essential is to remain totally realistic.

Simplified scheme for studying a fertilizer project

This deliberately simplified layout illustrates this method for approaching the problems.



ANNEX

PARTIAL ATTACK PROCESSES

INTRODUCTION

Processes for the complete attack of phosphates have been well known for many years: they result in obtaining phosphatic compounds which are more or less soluble and which generally pass rapidly into solution in the soil. These forms are universally used, irrespective of the characteristics of the soil. (Phosphoric acid is not generally used directly, but rather in the form of its salts such as mono- and di-ammonium phosphates.)

These processes require the employment of techniques which, although not of themselves too complicated, are nevertheless difficult and c⁻⁻tly to use. As we have seen in the main part of this report the use of these techniques leads to constraints on the chemical composition of the phosphate used, so limiting the number of types of phosphate which can be utilized.

Our experience has shown us that it was possible to use simple techniques to produce partially solubilized phosphates which, contrary to what might have been expected on first principles, were not a juxtaposition of solubilized and non-solubilized phases but rather products having rather unexpected properties.

These products are much more economical to manufacture and are, at the very least, as effective as those products resulting from total attack, if not in fact more effective.

Furthermore some of the constraints imposed on the phosphates used disappear, making it possible to use phosphates regarded as unusable when using the other customary techniques.

Whilst the techniques involved are simple the actual processes of attack call for fairly extensive studies in the laboratory, followed by agronomic trials designed to validate the efficacy of the products when they are used under the normal conditions of use (soils, plants and crops).

THE TECHNIQUES EMPLOYED

The following basic cha[illegible]tics need to be known :

Chemical analysis -

% P_2O_5
% CaO
% MgO
% Na_2O
% K_2O
% Al_2O_3
% Fe_2O_3
% SiO_2
% F^-
% Cl^-
% SO_3
% CO_2
% organic matter

Physical analysis -

Particle size distribution
Mineralogical characteristics
Porosity (specific surface area)

Miscellaneous -

Geological origin
Homogeneity of the product
Suitability for grinding

Tests for determining the treatment needed :

Laboratory

Systematic tests are to be carried out in the laboratory on attack by sulphuric and phosphoric acid and on mixed attacks. These involve -

The production on a laboratory scale of samples of products with various levels of attack and various conditions of attack (fineness of grinding of the phosphate, concentrations of the acids, etc.).

Studies on changes in the products with time (2, 8 and 24 days).

Tests on the mobility of the forms of P_2O_5 obtained (dynamics of extraction, solubilization curves).

Determination of the economic attack zones.

Analysis of the test products.

Analysis of the components (spectrometric analysis, etc.).

Pilot-scale plant

The production under semi-industrial conditions of samples intended for the agronomic trials.

Production of products in the following forms -
- Powders
- Run of Pile
- Granulated
- Compressed.

Tests on quality -
- Hardness and strength of the products
- Splitting
- Caking
- Compatibility with other fertilizing materials.

Optimization of the products -
- Quality
- Cost price
- Improvements in the mobility of the phosphatic forms.

Determination of the industrial parameters.

Selection of the technology to be utilized.

Agronomic tests

All the tests and trials carried out only lead to presumptions as to the agronomic efficacy of the products. These must now be verified by trials under glass and in the fields.

In fact experience makes it possible to limit the risks considerably, but modifications in detail can still be carried out to improve the results.

CONCLUSION

The totality of these tests may appear to be onerous, but the potential economies are very considerable (obtaining the product which is agronomically most efficacious at the minimum cost).

DESCRIPTION OF THE PROCESSES

There are two types of processes :

- Batch processes
- Continuous processes.

The choice between these processes is a function of :

- The quality of the phosphates to be processed, some treatments calling for successive attacks:
- The hourly quantity to be processed:
- The quality of the final products (P, PK, NPK):
- The physical form of the final product :
    - Powder
    - Granular
    - Compressed
- The desire or necessity to obtain a product directly granulated.
- etc.

It is necessary to distinguish between the following steps, which are found in all the possibilities :

- The grinding of the phosphate, the fineness being a function of the reactivity of the initial phosphate.
- The quantity of ground product used (with or without one or more other products).
- The preparation of the attack reagent (dilution and metering of the acids, mixing and metering of other solid or liquid products, the metering and addition of surfactants, bringing up to temperature, etc.).
- The first reaction stage (mixer).
- Maturation and possible granulation stage.
- Ripening stage (storage).
- Gas treatment stage.

The following stages are found in a conventional plant producing superphosphate :

- Grinding the phosphate.
- Diluting the acids.
- Metering the phosphate and the acid.
- Mixing before the holding tank.

- Superphosphate holding tank.
- Ripening store.

Moreover in the case of phosphates of standard qualities, or near the standard qualities, the technique for the manufacture of partially solubilized phosphates will be very similar to that of the superphosphates (control of the mixers).

THE ADVANTAGES OF PARTIAL SOLUBILIZATION

As from the time that agronomically efficacious products are obtained the following advantages have to be taken into account :

- Lower cost of the raw materials :
  - Use of phosphates of mediocre quality, local or imported;
  - Reductions in the usage of expensive products which are relatively difficult to manufacture (sulphuric and phosphoric acids);
  - In the case of sulphuric acid lower deconcentration of the products obtained.

  (The cost per unit of P_2O_5 obtained being sometimes only half that of the superphosphate which would be produced locally it may be seen, in the case of certain phosphates, that the quantity of soluble P_2O_5 obtained per unit of acid utilised is greater in the case of partial attacks than with total attacks.)

- A relatively simple operational technique which requires :
  - Lower capital investments;
  - A less sophisticated technological environment (semi-artisan type techniques can be used).
- The products obtained take into account the local cultivation conditions, so giving better results than the traditional products.
- The products can be granulated more easily.
- The products have greater compatibility with other fertilizers such as urea. (Use in bulk blending.)
- The total energy consumption is lower.

It is very difficult to give figures which are generally accurate: a calculation must be made for each case in order to take into account the characteristics of the raw materials which are available, the logistics cost, the level of production which is envisaged, the final products which are required, etc.

THE PROCESS

Three principal phases need to be distinguished :

A - The phase of preparing the products before attack, consisting of :

A1 - Preparation of the liquid products (metering, mixing, reheating, dilution, dissolving the added solid products, etc.).

A2 - Preparation of the solid products (metering, mixing, grinding, etc.).

B - The phase of reaction between the prepared products.
The reaction may be carried out on a batch or continuous basis, and in both cases in successive stages, involving one or more stages of maturation of the products or even a drying operation.

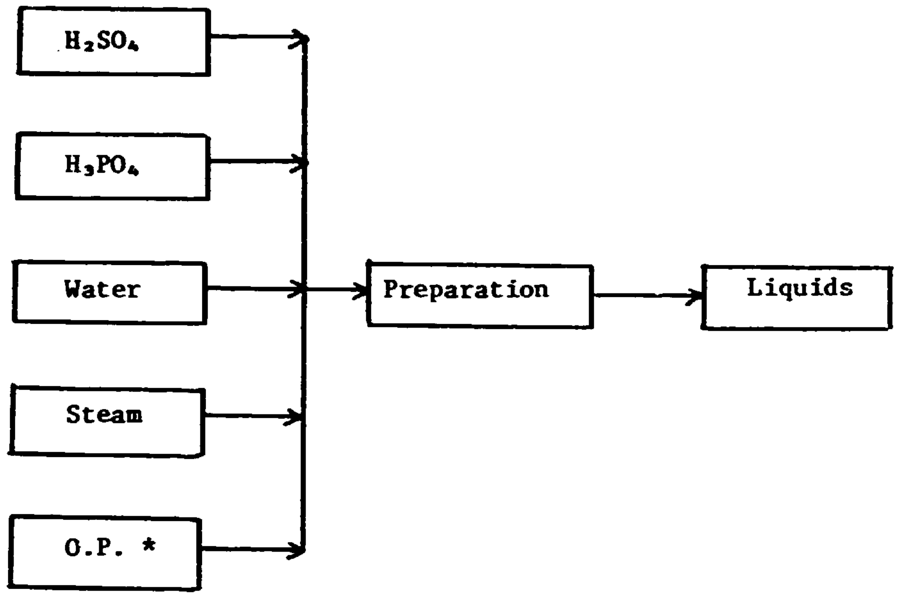
C - The phase of finishing the final product in order to obtain a product in one of the following forms :

- Powder
- Run-of-pile
- Granules
- Compressed.

Phases B and C can in some cases be carried out simultaneously (eg granulation during the attack phase).

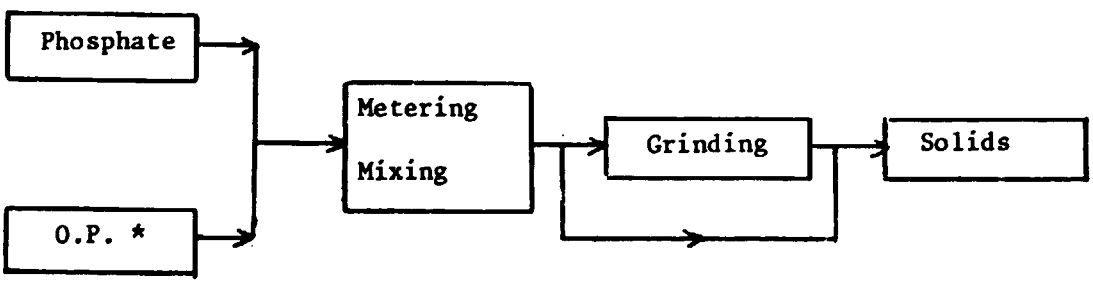
The various operations in these stages are shown in the figures and layouts on the following pages.

PHASE OF PREPARATION OF THE LIQUID PRODUCTS



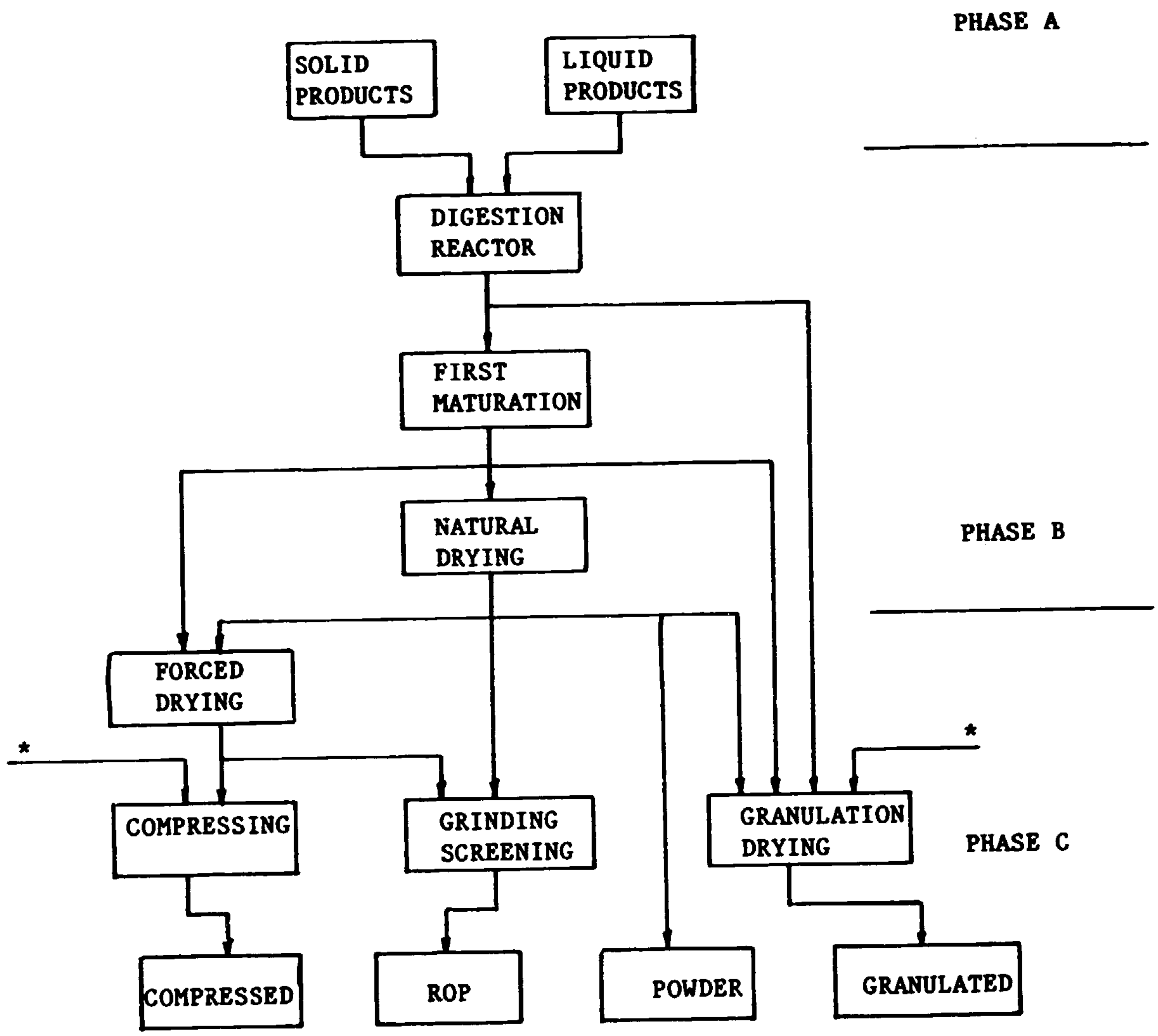
* O.P. = Other Products :
NH_3
Ammonia salts
Surfactants
Calcium salts
etc.

PHASE OF PREPARATION OF THE SOLID PRODUCTS



* O.P. = Other products :
Potassium salts
Ammonia salts
Calcium salts
Mg oxide and salts
etc.

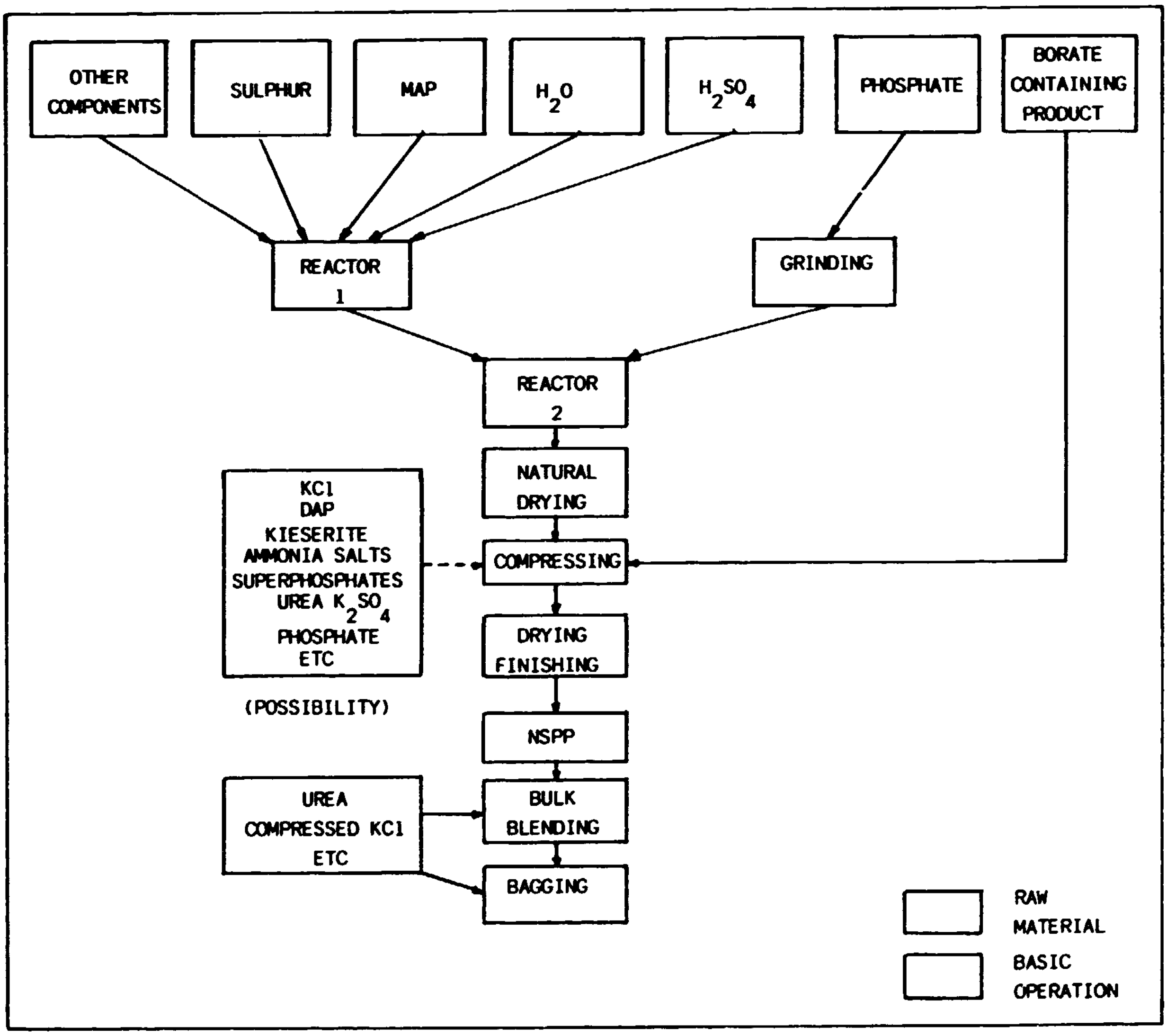
REACTION PHASE AND PRODUCTION OF FINAL PRODUCT



* OTHER SOLID AND LIQUID RAW MATERIALS

OUTLINE FOR WEST AFRICAN COUNTRIES

LAYOUT OF PRODUCTION



Workshop 1

Workshop 2

Workshop 3