FERTILIZER MANUFACTURING — PROBLEMS AND TENDENCIES

(Met opsomming 'in Afrikaans)

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Abstract

The purpose of this paper is to review briefly some of the technical problems which face the fertilizer producer in South Africa. Five major aspects of fertilizer production are discussed viz the efficient utilisation of raw materials, granulation, control of product composition, physical properties of products and effluent disposal.

Introduction

The fertilizer producer in South Africa, as elsewhere, must satisfy three different and sometimes conflicting sets of requirements:

Those of the consumer, who demands products which meet his agronomic needs, which are attractively priced, adequately packed and in good physical condition.

Those of the Government, which requires (among other things) that fertilizers sold to the consumer shall meet official regulations governing plant food content and that the producer shall maintain strict control over the disposal of effluents.

Those of the producer himself, concerned as he must be with protecting his capital investment and earning on it a reasonable rate of return.

TABLE 1. Consumption of Group 1 fertilizers in South Africa, 1967.

	Tons			
	Total	N	P	K
Mixtures/All grades	849790	64847	59935	61098
Nitrogen				
Ammonium sulphate	38130	8007	—	—
Urea	66734	30698	—	—
Limestone ammonium nitrate	129461	33643	—	—
Calcium cyanamide	57	13	—	—
Ammoniated super-phosphate				
2.5 N, 8.0 P	104798	2620	8384	—
5.7 N, 18.3 P	26202	1494	4795	—
Phosphates				
Superphosphate	373960	—	30823	—
Double super	23857	—	4676	—
Super and lime	45673	—	3425	—
Super and raw	85898	—	4896	—
Calmafos	25244	—	2020	—
Raw phosphate	155708	—	4360	—
Basic slag	20623	—	1444	—
Potassium				
KC1	31281	—	—	15640
K_2SO_4	4907	—	—	1963
Potash magnesia	1317	—	—	283
GRAND TOTAL	1983640	141322	124758	78984

(I) Data source: Soils Research Institute, Pretoria.

The purpose of this paper is to review briefly some of the major technical problems which face the South African producer in meeting these requirements.

Discussion

General pattern of South African production

Consumption of Group 1 fertilizers in South Africa during 1967 is summarised in Table 1.

Apart from straight nitrogen and potassium sources, the industry produces and supplies relatively low-grade products. The average analyses of mixtures and of all fertilizer materials supplied during 1967 are shown in Table 2 together with corresponding figures for the United States, which provide a useful standard of comparison. South Africa lags far behind in this respect, for reasons which are clear. The industry here, for example, still leans heavily on single superphosphate rather than double superphosphate, while the direct application of anhydrous ammonia is not yet practised on any large scale.

TABLE 2. Average analysis of fertilizers consumed: 1967.

Average % analyses all mixtures				Average % analyses all Group 1 fertilizers			
N	P	K	Total	N	P	K	Total
7.6	7.0	7.2	21.8	7.1	6.3	4.0	17.4
8.4	7.3	10.6	26.3	16.3	5.2	8.2	29.7

The whole question of upgrading, of balancing the undoubted advantages which more concentrated fertilizers offer to the consumer against the increased complexity and costs of production, represents a major problem to the producer. Its implications in the field of granulation will be referred to later.

Efficiency of utilisation of raw materials

The efficient utilisation of raw materials is of major importance to an industry in which raw materials costs form a substantial proportion of total production costs. In this respect the efficient utilisation of phosphate concentrate is of special interest, since the producer is here concerned with the chemical conversion of apatite to water-soluble or citric acid-soluble compounds of phosphorus.

South Africa is fortunate in possessing at Phalaborwa a very large reserve of phosphate rock, material from which Foskor produces a high-grade phosphate concentrate in quantities which are approaching the total requirements of the fertilizer industry. The Phalaborwa deposit is something of a mixed blessing, however, in that it is igneous in origin. Foskor concentrate, although high in grade, possesses virtually no internal surface and is highly unreactive by normal standards. It is interesting to recall that the use of Phalaborwa concentrate in phosphoric acid and superphosphate production was investigated in the United Kingdom some years ago (Dee, Nunn & Sharples, 1957). These workers reported that:

> "This rock has proved in the laboratory to be very unreactive.
> . . . we almost gave up attempts to obtain from this rock by acidulation a product with a high water-soluble P_2O_5 fraction.
> It seems that these igneous phosphate rocks are not well suited for the type of process which we are accustomed to use with the sedimentary phosphate rocks . . ."

The fact that Phalaborwa concentrate is now used in South Africa on a scale approaching one million tons annually in the routine production of phosphoric acid, single superphosphate and double superphosphate is a measure of the success with which the South African producer, at considerable expense, has grappled with this particular problem.

Although conversions now attained in Phalaborwa single superphosphate are high and satisfactory, there remains considerable scope for improvement in the fields of phosphoric acid and double superphosphate production. The producer is here concerned with minimising the cost of water-soluble phosphorus in his final product viz double superphosphate. This in turn calls for:

(a) a high overall phosphorous extraction efficiency in phosphoric acid production; and

(b) a high conversion of secondary rock phosphorus to water-soluble form in double superphosphate production.

To obtain some grasp of potential economies in the field, consider as an example the production of 100,000 tons per year of Phalaborwa double superphosphate at efficiencies of 94 per cent for phosphorus extraction in normal wet-process phosphoric acid production and 75 per cent for secondary rock conversion in double superphosphate production. Increases in these efficiencies to 95 per cent and 90 per cent respectively would result in a decrease of over 6,000 tons per year in total rock requirement, representing to the Highveld producer an annual saving in raw material costs approaching R100,000.

There is clearly a major incentive for research and development work in this field. It seems probable that further progress will hinge largely on fundamental physico-chemical studies on gypsum crystallisation and on basic work in the field of double superphosphate chemistry.

Granulation

One of the major needs of the consumer is a product in good physical condition, and quite the most important general advance in fertilizer technology in pursuit of this requirement was the introduction of granulation. Granular synthetic nitrogen materials were first produced in America in 1921, granular superphosphate made its appearance in 1929-30, and production of granular mixed fertilizers began about 1935 (Hignett & Slack, 1957). The practice of granulation developed rapidly in the years following the second world war, and since that time there has been a constant striving for cheaper and more efficient granulation processes.

These developments in due course spread to South Africa, where granular mixed fertilizers were first produced commercially in 1954, where again they rapidly found favour in the market, and where granulation has since become a well-established process. The major problem now facing the producer is to keep the cost of granulation within economic bounds.

Apart from urea and limestone ammonium nitrate, which will not be considered here, major interest in South Africa centres on granular superphosphate-based mixtures produced in rotary drum granulators. A striking feature of the granulation process is the almost total lack of any general physical theory applicable to systems encountered in fertilizer practice. The mechanism of granulation in simple solid-liquid systems such as sand and water is reasonably well understood (Newitt & Conway-Jones, 1958; Capes & Danckwerts, 1965; Kapur & Fuerstenau, 1966; Capes, 1967), and the theory has proved useful in its application to fertilizers based on mixtures of ammonium nitrate and ammonium phosphate. Such materials are amenable to theoretical treatment in that characteristics such as the variation in the volume of the liquid phase with temperature can be calculated, at least approximately, from the known properties of the constituents. Single and double superphosphate-based fertilizers represent considerably more complex systems which in general are not in equilibrium and in which, for example, variation in temperature is accompanied by both physical and chemical changes. In attacking basic problems which arise in the granulation of such materials the producer must lean heavily on his own past experience and on expensive semi-technical scale experimental work. There are few useful outside sources of information, the one outstanding example being the National Fertilizer Development Centre of the Tennessee Valley Authority at Muscle Shoals, Alabama.

Until quite recently the South African producer was concerned mainly with the granulation of low-grade fertilizers based on single superphosphate as the source of phosphorus. The granulation of such mixtures posed no major problems and a simple wetting and drying technique, with water as the granulation medium, proved adequate. With the onset of upgrading, however, and the partial replacement of single superphosphate by double superphosphate, granulation efficiencies have tended to fall. In order at least to maintain the capacity of his granulation plants in terms of the primary nutrients it has become necessary for the producer to seek more efficient and more sophisticated methods of operation, and this will be a continuing process. The elementary granulation techniques which sufficed for single superphosphate-based mixtures are quite certainly unsatisfactory for fully-upgraded double superphosphate-based fertilizers.

In dealing with some of the major practical problems which attend the granulation of superphosphate-based fertilizers it is convenient to consider three broad and inter-related aspects of the process:

(i) preparation and metering of raw materials, including recycle;

(ii) granulation *per se;* and

(iii) drying, cooling and screening.

The efficient preparation and accurate metering of raw materials represents the corner-stone of successful granulation practice. The physical condition of solid raw materials entering the granulator is of prime importance, and the producer must devote considerable attention to their preliminary treatment. The most difficult material to handle is almost certainly superphosphate, which tends to set hard in storage, to be costly to reclaim and to smear and cake badly in disintegrators and on screen cloths. In dealing with this problem the producer may well find it necessary to consider what improvements in the physical condition of mature superphosphate may be effected through modifcations in the production of superphosphate itself. The accurate metering of solid raw materials is again of major importance, and shortcomings in this operation will be reflected in difficulties both in granulation and in quality control.

There are two common approaches to the problem of weighing solids into the granulation process viz batch weighing, either manual or automatic, and continuous belt weighing (Bonser, 1959; Passmore, 1959; Waller, 1959). Of these, continuous belt weighing seems likely to be the cheapest in overall costs and is perhaps the most widely practised. The heart of a continuous belt weigher is the load-sensing system, which in early machines consisted essentially of a simple balance. More recently, electric and pneumatic load cells have been used for this purpose (Farquhar & Pollock, 1962; Lowe, 1965), and there have been interesting developments in this field in South Africa (Rome, 1966). Whichever system of belt weighing is selected by the producer, careful and conscientious maintenance and control are essential if it is to perform reliably and satisfactorily and if the machines are not to degenerate rapidly, in effect, into constant-volume feeders. The difficulties attending the maintenance of precision machines under normal fertilizer plant conditions need no emphasis.

Under normal circumstances of agglomeration granulation, a primary objective of the operator of a rotary drum granulator is a sustained high granulation efficiency, since granulation efficiency usually represents the controlling factor in determining the physical output of any given plant. The general principles of operation of rotary drum granulators have been discussed fairly fully in the literature (for example, by Hignett & Slack, 1957), but the translation of these principles into practice may afford some difficulties. The producer must achieve in the granulator a smoothly cascading bed of solids into which water, steam, ammonia, nitrogen solutions and acids are uniformly distributed separately or in combination and with minimum disruption of the solids flow. Some useful design guides have been published (Nielsson, 1961), but in general the producer must himself solve the engineering problems associated with the design and support of suitable gas and liquid headers. Build-up of material on the inner surface of the granulator, particularly in the vicinity of liquid headers, can be a most troublesome problem. Although high granulation efficiencies are in general desirable, the optimum efficiency is not necessarily the maximum attainable. If oversize handling, for example, represents a major source of difficulty in producing some specific mixture, then it may well be advisable to operate at something less than maximum efficiency. The problem facing the producer is essentially one of optimisation, and in its solution he must rely very heavily on experience and on the skill of his granulator operators. In principle, at least, the automatic control of a granulator through the continuous sampling and physical analysis of the output should be possible. In practice, the installation and maintenance of such an automatic control system would involve formidable expenditure.

The drying of solids in continuous rotary dryers is a common operation in fertilizer technology and one which raises problems associated both with the nature of the materials handled and with the nature of the process. The design of the very large units now in operation calls for some care to avoid excessive attrition or actual physical breakdown of the granules handled, with consequent overloading of dust extraction systems or significant loss of product. Build-up of sticky fertilizer dust on internal surfaces can lead to costly plant down-time for cleaning. The drying of high-analysis products containing substantial proportions of urea or ammonium nitrate demands particular care. The high temperature coefficient of solubility of these concentrated nitrogen sources, for example, can lead to most unwelcome post-granulation in the dryer itself. Cooling of the dried product is normally a straightforward process, but screening must receive special attention.

Other things all being equal, a wide product size range implies a minimum of recycle and a high plant output. A wide product size range, on the other hand, can result in serious practical difficulties in screening at the lower end of the size range, in marked segregation in bulk storage, and in unacceptable variations in the physical properties of the bagged product. The producer is here faced, again, by a difficult problem in optimisation which he must solve within his own particular constraints.

Control of product composition

It is entirely in the producer's interest that the plant nutrient content of his bagged products conforms as closely as possible with the nominal analysis printed on the bags. If his products fail to meet this requirement he risks prosecution under official regulations which, though they represent a notable example of enlightened technical legislation, are naturally framed to protect the consumer (S.A. Government, 1963). If his product analyses exceed the nominal values, he loses money. In an industry in which raw material costs form a high proportion of the total cost of the product, and in which the return on capital employed is in any case not particularly attractive, close control of product composition is of major economic importance.

Control of composition of granular fertilizers demands attention to almost every detail of the production process, from the production of raw materials and intermediates through to the bagging of the final product. The production of uniform grades of single and double superphosphate, the accurate metering of raw materials into the granulation process, the control of physical and chemical process losses, the handling and reworking of spillage and the control of contamination during storage and bagging are some of the technical problems which arise.

Granulation is a recycle process and in a large plant there may be upwards of 100 tons of material in circulation at any given time. This leads to particular difficulties during start-up, when in the author's experience such a plant may take 8 hours or more to reach equilibrium, and during change-overs from one mixture to another. Almost inevitably, during such periods, substantial quantities of off-grade product leave the plant and must be separately stored and later re-worked, with all the additional expense involved in double handling. Careful production planning can help to minimise these problems, but their primary cause is the multiplicity of mixtures which the producer is required to granulate.

At least two systems of close quality control are practised in the industry:

(i) Backward steering, in which process control is effected on the basis of frequent analysis of the product leaving the plant.

(ii) Forward steering, in which product composition is controlled primarily through close control of raw material input rates.

Either approach involves a substantial effort — the first calls for the provision of analytic services throughout the 24 hours, and the second demands trained personnel to operate and control raw materials metering equipment. The producer must weigh the cost of these measures against the legal and financial consequences of failure to maintain satisfactory control of product composition.

Physical properties of products

The importance to the fertilizer consumer of satisfactory physical properties needs no emphasis. Products which are damp, which cake in storage, which smear and build up in farm distribution machinery, raise immediate and justifiable complaints.

Some of the factors governing physical condition of granular products have already been mentioned. Product size range depends partly upon the initial choice of apertures for product and oversize screens in the granulation plant and, almost equally important, upon the efficient operation and maintenance of these screens under difficult working conditions. Granule hardness may be controlled, at least to some extent, through control of granulation process conditions and granule moisture content. Granular double superphosphate and ammoniated double superphosphate both posed problems for the producer in this respect when they were initially marketed in South Africa. High-analysis granular fertilizers almost invariably need some form of coating or conditioning treatment as an aid in attaining satisfactory storage and flow properties. The producer must determine by experiment on his own products what treatments are adequate and economically feasible.

There would be little point in striving to meet the requirements of the market at the production plant unless the product could be adequately protected in its passage from factory to consumer. A major step forward in the packaging of fertilizers was the displacement of the paper bag by polythene, a process which began in South Africa in 1962-63, which has since gone virtually to completion and which has been generally welcomed both by the railways and by the consumer (Gillespie, 1965).

Effluents

No discussion of problems in fertilizer production would be complete without some mention, however brief, of effluents. In this respect the fertilizer industry, in common with industry generally in South Africa, is coming under increasingly close official scrutiny, and the subject of effluent emission and control has become a major branch of technology in its own right.

It is unnecessary to dwell on the difficulties which the fertilizer producer must overcome in dealing with effluents in general, and with fluorine and gypsum in particular, but one point is worth making. There is an increasing tendency, born perhaps of necessity, to regard effluents not as a profit-eroding nuisance but as a potentially valuable source of materials and products.

An excellent example of this approach is afforded by the large-scale use of liquid nitrogenous effluent as a direct-application fertilizer on grassland (Lever, 1966).

Conclusion

The purpose of this paper was to review briefly some of the technical problems which face the South African fertilizer producer.

The rapidly-expanding fertilizer industry in this country has made substantial technical progress in recent years and will undoubtedly continue to do so. Its biggest future problem may well be to attract and keep men of the necessary ability, knowledge and enthusiasm to maintain the pace of progress.

Opsomming

KUNSMISVERVAARDIGING-PROBLEME EN NEIGINGS

Die doel van hierdie referaat is om 'n oorsig te gee van die tegniese probleme waarmee die kunsmisprodusent in Suid-Afrika te kampe het. Vyf hoofaspekte van kunsmisvervaardiging word bespreek nl. die doeltreffende benutting van grondstowwe, verkorreling, beheer van produk-samestelling, fisiese eienskappe en verwydering van vloeibare fabrieksafval.

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