

ISMA* Technical Conference

Helsinki, Finland
3-5 September 1963

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

THE USE OF A NEW FORM OF MONAMMONIUM
PHOSPHATE IN PLACE OF SUPERPHOSPHATE
AS A MEANS OF ATTAINING HIGHER
CONCENTRATION IN GRANULAR NPK
FERTILISER

By I.A. Brownlie and R. Graham,
(Scottish Agricultural Industries Ltd., U.K)

1. INTRODUCTION

The superphosphate industry had its origin in the work of Escher, Liebig and Lawes in the period 1835-1842 and in 1842 letters patent were issued in Great Britain to Lawes and Murray for manufacturing superphosphate. Lawes purchased Murray's patent and, erecting a superphosphate works in England, remained the sole controller of the manufacturing process until 1872. Lawes can be said to have been the beginning of the global industry in superphosphate which today amounts to about 4.3 million tons of P_2O_5 . During the past 100 years, however, and particularly during the past fifty years, other forms of solubilised P_2O_5 have challenged the production and sale of single or normal superphosphate. These include phosphoric acid, enriched superphosphate, triple superphosphate, mono- and di- ammonium phosphate, and we are now entering the period when superphosphoric acid, calcium and potassium metaphosphates, ammonium polyphosphates, etc. will no doubt grow in importance.

The prime reason for replacing superphosphate, of course, is the need for increased concentration of plant foods. Many types of plant both batch and continuous were designed for superphosphate manufacture over the years but basically superphosphate remained a low cost form of soluble P_2O_5 . The need for greater concentration of plant foods has inevitably led to greater manufacturing cost, particularly as the first stage in all of the products mentioned above, except superphosphate, involves phosphoric acid manufacture. It is necessary therefore that (a) the succeeding stage of conversion from phosphoric acid to the solid form should be a cheap one; (b) the material should

be as concentrated as possible; (c) it should be easily incorporated in granular NPK fertilisers; (d) it should store well; and (e) it should be capable of being transported easily in bulk and handled in conventional equipment. The production of such a material formed a worthwhile challenge not only because of the tremendous global target of P_2O_5 tonnage as superphosphate which could be converted but also because of the increasing tendency to convert phosphate at the source to a soluble concentrated form of P_2O_5 with the object of saving shipping and transport costs.

2. DEVELOPMENT AND PROPERTIES OF THE NEW PRODUCT

The purpose of this paper is to describe the properties and usage of a new form of ammonium phosphate which satisfied all of the above conditions and has already been well tried in the United Kingdom in substantial quantities over the past two years. Unfortunately the method of manufacture cannot be revealed in this paper, as it is the subject of patent applications (1) but basically it is as simple as the original superphosphate process without, of course, the need for curing the product.

The product is, however, as interesting as the process and perhaps an account of how it came to be discovered would be useful. S.A.I. have been working for several years on an ammonium phosphate replacement for superphosphate and an earlier paper(2) to the 1959 I.S.M.A. Conference on the use of granular ammonium phosphate will be recalled. In this paper it was shown that the use of a form of crystalline monammonium phosphate, from which had been removed certain impurities such as iron and aluminium phosphates, originally present in wet process phosphoric acid, would not granulate with ammonium sulphate and potassium chloride. The successful production of NPK fertilisers, using ammonium phosphate in the form of small granules as a nucleus surrounded by a shell of other fertiliser constituents, was described. Work on the production of various forms of ammonium phosphate was continued and about three years ago S.A.I. were considering the supply to customers of ammonium phosphate in slurry form for delivery by road tanker. When the basic design of tanker for road transport of slurry was being investigated, it was found that although monammonium phosphate slurry solidified on cooling to give

an apparently solid mass of crystalline material this mass could be brought to a fluid or thixotropic condition by stirring. It appeared that this interesting physical property could be taken advantage of by allowing a fair degree of cooling prior to use provided that sufficient agitation of the slurry magma was employed during transport and storage.

Experiments were continued and it was found that solid monammonium phosphate had the property that if the moisture content was above, say, 15% the product could be worked into a fluid mass although it appeared to be solid and easily handled if not so worked. Moreover, if the moisture content was lower, no amount of physical handling, vibration or pressure could soften or liquefy it. The thixotropic property was thus found to be critically dependent on moisture content. From these experiments it was deduced that if solid monammonium phosphate could be produced at a moisture content between 6% and 12% it would have properties beneficial to granulation in a conventional granulation plant. If such solid monammonium phosphate were fed into a plant using steam for granulation, its incorporation in an NPK fertiliser would be similar to that achieved with superphosphate. Additional moisture in the form of steam would quickly bring the monammonium phosphate to the thixotropic stage and would aid granulation. This is different from granular monammonium phosphate where the initial moisture content is similar to that of the ammonium sulphate and potassium chloride, i.e. below 1% and addition of moisture, increasing the moisture content of all the components by approximately the same amount, overwets the ammonium sulphate and potassium chloride constituents. It was believed that solid monammonium phosphate containing 6%-12% moisture would give a more homogeneous NPK product than that obtained with granular monammonium phosphate.

Development of a process for producing a form of ammonium phosphate in a powder form and containing between 6% and 12% moisture according to requirements was successfully completed. It is basically a simple process with a capital cost about one quarter of the cheapest published process for ammonium phos-

phate using ammonia and wet process phosphoric acid. Power and labour costs are also low. The product was found to be similar in appearance and properties to matured single superphosphate with the added advantage that it contained about 60 plant food units compared with about 20 units in superphosphate.

A typical chemical analysis of the product using Nauru phosphate as the P_2O_5 source is 11.5% Nitrogen, 47% water soluble P_2O_5 and 48% total P_2O_5 with a moisture content of about 6%. It is estimated that a typical chemical analysis based on Morocco phosphate would be 11% Nitrogen, 50% water soluble P_2O_5 and 51.5% total P_2O_5 . A typical screen analysis of this material is approximately as follows:-

	%
+ 5 mesh B.S.S.	= 6
- 5 + 7 " "	= 10
- 7 + 12 " "	= 15
- 12 + 16 " "	= 12
- 16 + 30 " "	= 19
- 30 " "	= <u>30</u>
	100

Bulk Density = 55/60 lb. p. cu. ft. untamped.
The preferred moisture content ranges for the various forms of ammonium phosphate derived from Nauru rock by the new process are given in Table I. By the N/ P_2O_5 ratio of ammonium phosphate is meant the ratio of the total weights of N and P_2O_5 contained in the product in any chemical form.

TABLE I

N/P Atomic Ratio of Ammonium Phosphate	Other Component	N/ P_2O_5 Weight Ratio	Preferred Moisture Range %
0.95	-	1:4	6-12
1.3 - 1.6	-	1:3.5-1:2.8	3.5- 9
1.0	Ammonium Sulph.	1:2	5-10
1.0	- do -	1:1	4- 9
1.0	- do -	2:1	3- 8
1.6	- do -	1:2	4- 9
1.6	- do -	1:1	4- 8
1.6	- do -	2:1	3- 7

The product which is sold in the United Kingdom under the registered Trade Mark "PhoSAI" has excellent storage properties and can be stored satisfactorily in bulk as shown in Figure I which is a photograph of a bulk store containing about 1,200 tons of "PhoSAI". Storage of ammonium phosphate in this way reduces the requirements of storage for P_2O_5 in the form of phosphoric acid.

FIGURE I



3. PRELIMINARY GRANULATION TRIALS

In the beginning it was necessary to carry out granulation trials to determine the properties of "PhoSAl" and these were done on one of our granulation plants which is equipped with an Eirich granulation pan and has a capacity of about 5 tons per hour. Raw materials are batched into this plant but the rest of the process, namely drying, cooling and screening is continuous. The product screens were set at 1 mm and $3\frac{1}{2}$ mm and "PhoSAl" was batched into the process with the other raw materials.

The results and operating conditions are shown in Tables II, III and IV. During the period of the trial about 250 tons of $13\frac{1}{2}:13\frac{1}{2}:13\frac{1}{2}$, 12:12:18 and 15:10:10 were made.

TABLE II
DRIER FEED CONDITIONS

FORMULA	AVERAGE DRIER INLET MOISTURE	DRIER FEED			
		Batches per hr.	Raw Materials Cwt/batch	Fines Cwts/ Batch	Total Tons/ Hour
	%				
$13\frac{1}{2}:13\frac{1}{2}:13\frac{1}{2}$	7.7	8	10	8	7.2
12 :12 :18	9.3	8	10	8	7.2
15 :10 :10	7.2	6	10	8	5.4

It was found possible to granulate 12:12:18 and $13\frac{1}{2}:13\frac{1}{2}:13\frac{1}{2}$ and 15:10:10 compositions. The temperature in the pan was achieved by the use of steam and it was desirable to have a temperature of at least 140°F.

Product quality of the fertilizer produced was satisfactory and outputs achieved on $13\frac{1}{2}:13\frac{1}{2}:13\frac{1}{2}$, and 12:12:18 were 4 tons per hour with no indication that this was necessarily the upper limit. It was clear that granulation on a conditioner type plant would be even better.

In the assessment of granulation performance it is helpful to show the results in terms of the moisture requirements expressed

as tons of water per ton P_2O_5 since S.A.I. have a range of products with widely differing P_2O_5 content. The results in Table II have been converted in Table V to moisture requirements for granulation in tons water per ton P_2O_5 .

TABLE III
SCREEN ANALYSIS OF RAW MATERIALS

Screen Size B.S.S.	Ammonium Sulphate %	Potassium Chloride %		"PhoSAI" %
		(a)	(b)	
+ 5	-	-	-	6
- 5 + 7	-	-	-	10
- 7 + 12	1.7	1.5	0.7	15
- 12 + 16	9.0	2.0	0.2	12
- 16 + 30	51.2	15.7	23.5	19
- 30 + 60	30.7	52.8	37.5	18
- 60	7.4	28.0	38.1	20
	100.0	100.0	100.0	100

TABLE IV
RANGE OF OPERATING CONDITIONS

Reading	Values
Inlet Gas Temperature °F	700 - 840
Exit Gas Temperature °F	215 - 250
Exit Drier Solids Temperature °F	230 - 260
Drier Feed Temperature °F	100 - 140
Recycle Temperature °F	140 - 160
Fines Recycle Tons per Hour	2 - 4
- 5 + 16 mesh B.S.S. ex Drier %	30 - 75
"PhoSAI" Moisture %	8 - 10
Drier Feed Moisture %	7 - 9.5
Exit Drier Moisture %	0.1 - 0.6

MOISTURE REQUIREMENTS FOR GRANULATION

FORMULA	Tons P_2O_5 /hr.	Moisture Tons/hr.	Water Tons/ton P_2O_5
13½:13½:13½	0.54	0.55	1.0
12 :12 :18	0.48	0.67	1.4
15 :10 :10	0.30	0.39	1.3

It will be observed from Table V that the moisture requirements for granulation with "PhoSAI" in these experiments were in the range 1.0 - 1.4 tons water per ton P_2O_5 .

4. GRANULATION PLANTS ON WHICH "PhoSAI" HAS BEEN USED

All of the above work took place before putting "PhoSAI" on the market but "PhoSAI" has now been used on a large number of granulation plants, most of which can be described as conventional, and no plant modification of any sort has been found necessary. In other words, it can be handled and used in the same way as conventional raw materials.

These granulation plants, while they are of the same basic design, differ from each other in a number of ways and general information on the variations in types of plant successfully used is given below.

(a) Preparation Unit. This unit normally contains an elevator, intermediate storage hoppers and a batch weighing hopper. It may or may not contain milling and screening equipment. Raw materials are fed into the elevator which discharges them into the appropriate raw material intermediate storage bin. From there the materials are fed either by gravity or feeding device, i.e. vibrator feeders into a weighing hopper in the required proportions, before being discharged to a mixing unit. When milling and screening equipment is available the raw materials are normally milled and screened before entering the storage bins although on some plants the weighed batch of different ingredients is milled and screened.

(b) Mixing and Feed Control Unit The most common piece of equipment used for mixing is a batch horizontal rotary tumbler mixer, normally fitted with internal devices, e.g. baffle plates

to assist in obtaining homogeneous mixtures. In some plants the undersized material or "fines" are returned to the mixer as a batch along with the raw materials, while in others the "fines" are returned at a later stage.

The mixed batch is discharged to a surge hopper where control of the raw material feed to the plant is normally obtained by using an adjustable gate valve. A similar control is used on some occasions for the "fines" recycle which is returned to a separate surge hopper.

A few continuous mixers are used and in these the feed to the conditioner is controlled at a constant volume by a bucket discharge arrangement at the exit.

(c) Granulating Unit By far the most popular piece of granulating equipment found in plants which have used "PhoSAI" is the horizontal rotary conditioner or tube, although horizontal pan mixers are used successfully. Rotary conditioners used vary greatly in their dimensions, peripheral speed and materials of construction. Most are equipped with steam which is essential for the production of highly concentrated fertilisers, but steam pressure, degree of saturation and the design and construction of steam nozzles are different in nearly every plant.

(d) Drying Units. Without exception the unit used to dry the fertiliser discharge from the conditioner is a horizontal, rotary, co-current drier fired by oil or coal. A number of driers have automatic temperature control normally based on the temperature of the gases leaving the drier, but on one plant temperature control is based on measurement of the moisture content of the solids leaving the drier by a capacitance type moisture meter. The dimensions and peripheral speeds of the driers used vary over a wide range, but no information is available on residence time, gas volumes or evaporative capacities related to throughputs.

(e) Cooling Units Two types of coolers are used. The most common is the horizontal rotary counter-current cooler, but a few fluidised bed coolers are also used.

(f) Screening Equipment. There is a wide variation in the type

of screens in use. In wide use are mechanically vibrated inclined screens and oscillating screens, while a few electrically vibrated screens are also employed.

(g) Milling Equipment. Oversize material formed during the manufacture of concentrated fertilisers using "PhoSAI" has been satisfactorily handled in each plant by the oversize breaking equipment present. These include simple single and double cage mills, flail mills, hammer mills, and roll mills.

(h) Gaseous Effluent Discharge. In our experience from visual observation, the gaseous effluent from a plant using "PhoSAI" is much less dense than the effluent normally discharged from plants manufacturing superphosphate based fertiliser.

5. OTHER MATERIALS USED TO OBTAIN CONCENTRATION IN FERTILISER

For a long time, triple superphosphate has been the most important material used to increase fertiliser concentration above that normally achieved with single superphosphate, i.e. above say a 9:9:9 grade.

More recently Urea has become popular as a source of nitrogen because it can be used to either (a) increase the degree of concentration obtainable with triple superphosphate, or (b) maintain the existing concentration by allowing more single superphosphate to be used, and thus obtaining a cheaper formulation. With Urea, of course, strict drier temperature control at about 85° to 90° for solids is essential to prevent ammonia losses and subsequent reversion of soluble P_2O_5 . Moreover with formulations containing a fairly high proportion of Urea, say 10%, coating of the product to prevent setting may be necessary, but this depends on the formulation and the condition of the fertiliser produced.

With the increased demand for concentration some manufacturers find it necessary to use di-ammonium phosphate, with the result that drying conditions have to be strictly controlled at an even lower temperature and coating of granules has to be carried out with most formulations. Moreover granulating conditions become critical and cognisance has to be taken of the size specification and crystal shape of other raw materials used, e.g. ammonium sulphate.

The most recent drive towards very concentrated high nitrogen fertilisers has led to the use of ammonium nitrate in some instances.

6. SOME OPERATIONAL ASPECTS OF MANUFACTURE WITH "PhoSAI"

"PhoSAI" has been used to manufacture a wide range of concentrated fertilisers and information on operational aspects of manufacture is given below. This information has been obtained from S.A.I. work and from other manufacturers who have used "PhoSAI".

A comparison of Granulation Moisture Requirements

(a) NPK fertilisers based on different forms of monammonium phosphate

In Table VI the granulation moisture requirements on full scale plants for a 12:12:18 fertiliser are shown using different forms of monammonium phosphate, the other ingredients being ammonium sulphate, potassium chloride and single superphosphate. Information for a 10:10:18 grade based on "PhoSAI" is also included.

The results show clearly that the granulation moisture content is considerably lower with "PhoSAI" than for other forms of monammonium phosphate. This means that drying costs per ton of product are lower if "PhoSAI" is used as the source of P_2O_5 in fertilisers. Furthermore with the exception of ammonium phosphate slurry, the average moisture content of the raw materials is highest when "PhoSAI" is used and consequently the amount of added moisture necessary to achieve granulation is smaller. This moisture is normally added as steam so that the significant reduction in steam requirements means a reduction in the cost of steam per ton of product.

(b) NPK fertilisers based on "PhoSAI", diammonium phosphate and triple superphosphate.

The source of P_2O_5 in concentrated fertilisers manufactured on conventional granulation plants is usually either triple superphosphate, monammonium phosphate or diammonium phosphate. The results in Table VII for 12:12:18 fertiliser show a much lower granulation moisture content for "PhoSAI" when compared with diammonium phosphate and as a consequence fertiliser drying costs and steam raising costs should be greatly reduced.

TABLE VI - MOISTURE REQUIREMENTS FOR GRANULATION WITH MONAMMONIUM PHOSPHATE IN DIFFERENT FORMS

FERTILISER GRADE	FORM OF MONAMMONIUM PHOSPHATE	GRANULATING UNIT	GRANULATION MOISTURE CONTENT % wt.	AVERAGE MOISTURE CONTENT OF RAW MATERIALS % wt.	MOISTURE CONTENT TO BE ADDED AS STEAM % wt.	GRANULATION MOISTURE CONTENT TONS H ₂ O PER TON P ₂ O ₅	REMARKS
12:12:18	"PhoSAI"	Horizontal pan	9.1	2.0	7.1	1.4	
12:12:18	Pure Crystalline	Horizontal pan	-	-	-	-	Did not granulate properly.
12:12:18	Slurry	Horizontal pan	11.1	-	-	2.1	
12:12:18	"PhoSAI"	Rotary Conditioner	6.4	2.0	4.4	0.8	
+12:12:18	Granular	Rotary Conditioner without pin granulator	11.9	0.5	11.4	2.5	
+12:12:18	Granular	Rotary Conditioner with pin granulator	10.7	0.5	10.2	1.9	
10:10:18	"PhoSAI"	Rotary Conditioner	7.1	2.5	4.6	1.0	

+ Runs carried out on same plant

TABLE VII

GRANULATION MOISTURE REQUIREMENTS WITH
"PhoSAI" OR DIAMMONIUM PHOSPHATE
 (No Urea present)

Fertiliser Grade	Source of P_2O_5	Granulating Unit	Granulation Moisture Content ton H_2O /ton P_2O_5
12:12:18	"PhoSAI"	Horizontal Pan	1.4
12:12:18	D.A.P. Granules	" "	1.9 - 2.2
12:12:18	"PhoSAI"	Rotary Conditioner	0.8
12:12:18	D.A.P. Granules	Rotary Conditioner	2.5 - 2.9

Similarly in Table VIII results are shown for two 16:9:9 formulations carried out on a pilot plant scale using the same raw materials other than the P_2O_5 bearing materials, and in order to show that the granulation moisture requirements are of the right order when compared with those for a full plant scale, information obtained on a 16:8:8 fertiliser is included. The results demonstrate the lower steam requirements necessary with "PhoSAI" as well as the lower granulation moisture requirements which would result in reduced drying costs.

Formulations Manufactured with "PhoSAI"

A large number of different grades of fertilisers have been manufactured on conventional plants using "PhoSAI". Some information is given in Table IX on the moisture contents for granulating a number of fertilisers using "PhoSAI" as the main source of P_2O_5 . Some of the products successfully made using "PhoSAI" are illustrated in the photographs shown in Figures 2, 3 and 4. A photograph of the typical rolling bed in a conditioner when using "PhoSAI" is shown in Figure 5.

TABLE VIII - GRANULATION MOISTURE REQUIREMENTS WITH "PhoSAI" AND TRIPLE SUPERPHOSPHATE

(Urea present)

FERTILISER GRADE	GRANULATING UNIT	SOURCE OF P ₂ O ₅	GRANULATION MOISTURE CONTENT % wt.	MOISTURE CONTENT OF RAW MATERIALS % wt.	MOISTURE ADDED AS STEAM % wt.	GRANULATION MOISTURE CONTENT ton H ₂ O/ton P ₂ O ₅
16:9:9	Rotary Conditioner Pilot Plant	"PhoSAI"	4.2	2.7	1.5	0.6
16:9:9	" "	Triple Superphosphate	5.6	2.1	3.5	0.8
16:8:8	Rotary Conditioner Full Scale Plant	"PhoSAI"	3.25	2.2	1.05	0.6

In general the products made are:-

- (i) high nitrogen fertilisers ranging from 14:7:7 to 20:10:10
- (ii) high P_2O_5 fertilisers ranging from 10:15:10 to 12:24:12
- (iii) high K_2O fertilisers ranging from 9:9:25 to 13:13:20

The 1:1:1 fertilisers such as $13\frac{1}{2}:13\frac{1}{2}:13\frac{1}{2}$ have also been produced.

Drying Temperature with "PhoSAI"

When "PhoSAI" is used to supply all or part of the P_2O_5 in granular compound fertilisers, the temperature of the solids leaving the drier can be maintained at 120/125°C with no ammonia loss and no reversion of soluble P_2O_5 to an insoluble form. When other materials which are more heat sensitive than "PhoSAI"; e.g. Urea, ammonium nitrate, etc. are used in the mix then the temperature of the solids leaving the drier must, of course, be reduced.

Keeping Qualities of fertiliser Produced with "PhoSAI"

Tests were carried out by one manufacturer on the keeping qualities of fertiliser made with "PhoSAI". Plant runs were made on the same grade of fertiliser using (a) "PhoSAI" and (b) triple superphosphate as the main source of P_2O_5 . The results showed that for the same plant load and exit drier temperatures the moisture content of the product made with "PhoSAI" was lower than that for the product made with triple superphosphate. Furthermore on concentrated fertilisers this manufacturer finds that with "PhoSAI" he is able to dry the product to a moisture level low enough to prevent caking. On the same fertiliser made with triple superphosphate he is unable to do this.

"PhoSAI" can be used in the production of powder NPK fertilisers for horticultural applications and in these products a reduction in caking has been obtained when compared with the equivalent superphosphate based products.

The Use of "PhoSAI" to Produce Granular Ammonium Phosphate

"PhoSAI" can be granulated by itself with a high granulation efficiency on conventional plants. Moisture requirements using a horizontal pan as the granulating unit vary

TABLE IX - GRANULATION MOISTURE CONTENTS FOR VARIOUS FERTILISERS USING "PhoSAI"
AS THE MAIN SOURCE OF P_2O_5

FERTILISER GRADE	SOURCE OF P_2O_5	UREA PRESENT	GRANULATING UNIT	GRANULATION MOISTURE CONTENT % wt.	MOISTURE CONTENT OF RAW MATERIAL % wt.	MOISTURE TO BE ADDED AS STEAM % wt.	GRANULATION MOISTURE CONTENT ton H_2O per ton P_2O_5
$13\frac{1}{2}:13\frac{1}{2}:13\frac{1}{2}$	"PhoSAI"	No	Horizontal Pan	6.6	2.0	4.6	0.9 - 1.0
15 :10 :10	"PhoSAI"	No	Horizontal Pan	7.2	1.6	5.6	1.3
20 :10 :10	"PhoSAI"	Yes	Rotary Conditioner	2.5	1.5	1.0	0.4
13 :13 :20	"PhoSAI"	Yes	Rotary Conditioner	3.0	2.2	0.8	0.3

FIGURE 2

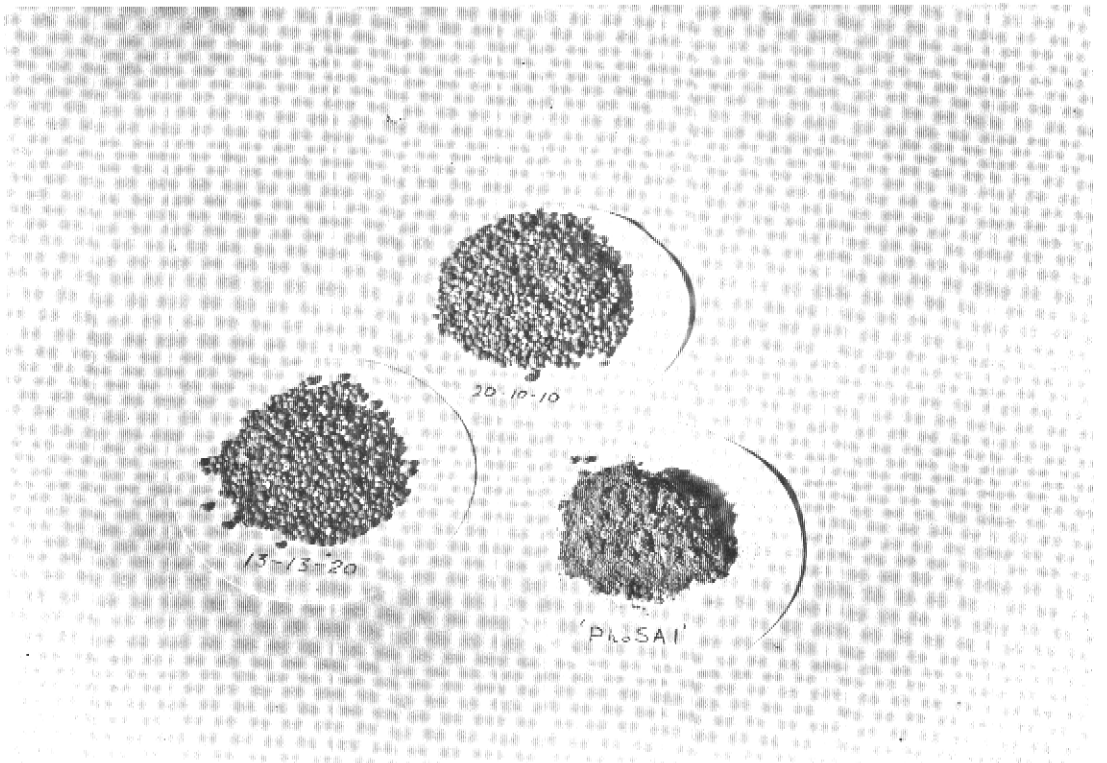


FIGURE 3

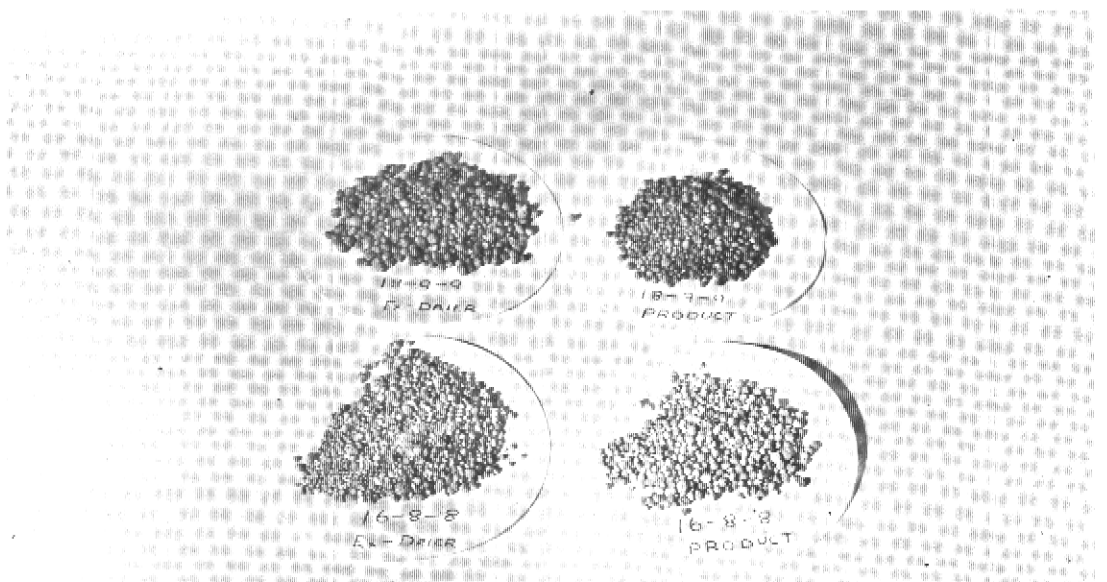


FIGURE 4

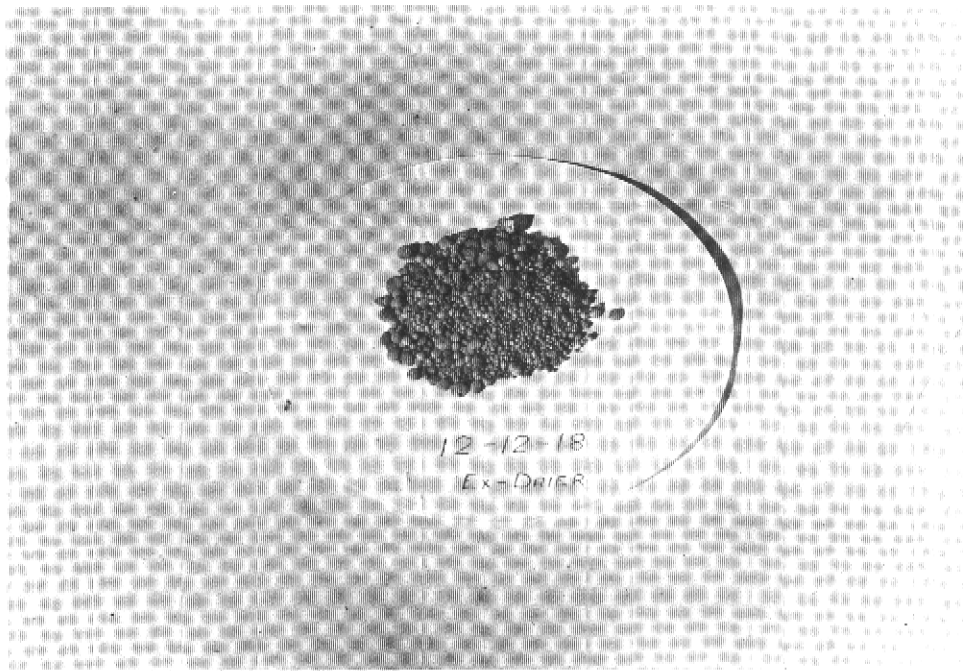
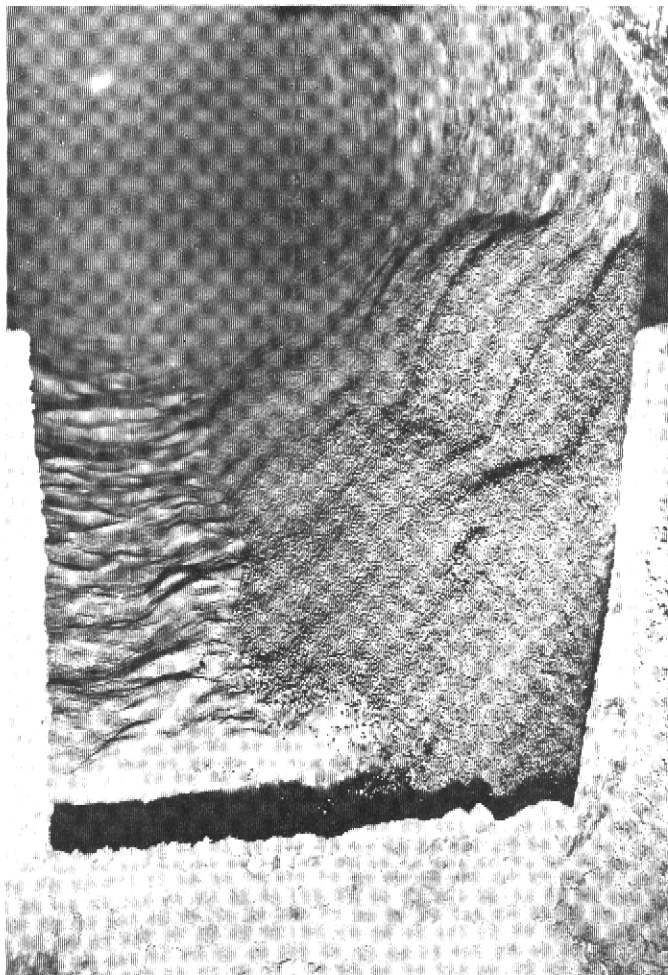


FIGURE 5



from 0.4 to 0.5 tons water per ton P_2O_5 . With a product moisture content of under 1% a typical analysis of the granular material is 12.5% Nitrogen, 50% water soluble P_2O_5 and 51% total P_2O_5 . The granules produced are hard and well formed and can be used for bulk blending or direct distribution as required.

7. SUMMARY AND CONCLUSION

This paper reviews the work done on the development of a new form of monammonium phosphate suitable for incorporation in granular NPK fertilisers. This product is in powder form similar in appearance and characteristics to superphosphate, and it has been shown that its granulation properties are superior to other forms of ammonium phosphate. In general the granulation moisture requirements for "PhoSAI" in NPK fertiliser production are lower and consequently the cost of steam required, and the cost of fuel for the subsequent drying stage are reduced when compared with other forms of ammonium phosphate.

Similar improvements in granulation with "PhoSAI" have been shown in comparison with triple superphosphate and diammonium phosphate as the P_2O_5 sources. The new product can be stored satisfactorily in bulk without caking or moisture pick-up, and can be handled in conventional feeding equipment. No additional equipment is required in normal granulation plant, and when "PhoSAI" is used in conjunction with superphosphate, ammonium sulphate and potassium chloride, temperatures ex drier up to $125^{\circ}C$ can be used without build-up in the drier, ammonia loss, or reversion of soluble P_2O_5 in the product. In presence of Urea the drier exit temperature has to be lower (about $85-90^{\circ}C$) but granulation and drying of the product are satisfactory and generally processing is easier and product quality better than with similar formulations using Urea and granular diammonium phosphate raw materials.

The new product has been found attractive by manufacturers who make their own superphosphate, since in conjunction with Urea, in certain formulations it permits the incorporation of substantial quantities of superphosphate, thus cheapening the overall cost of the raw materials used.

The manufacturing process for S.A.I. ammonium phosphate has been the subject of patent applications and full details

cannot yet be released. It is, however, a simple process which is eminently suitable for converting P_2O_5 into a low cost ammonium phosphate suitable for transport over long distances. It is believed that this new material will be a suitable replacement for superphosphate in the move towards more concentrated fertilisers and that it will be suitable for phosphate rock producers who wish to solubilise P_2O_5 at the source for supply to world markets. In general the product is superior in properties to, and of lower cost than, the 'pin-head' granular product described by S.A.I. at the 1959 I.S.M.A. Conference, and the claims made for its properties have been already proved by the large scale manufacture of many thousands of tons per annum by S.A.I. and its wide spread commercial acceptance by the fertiliser industry in the United Kingdom over the past two years.

8. ACKNOWLEDGEMENTS

The Authors wish to thank the Directors of Scottish Agricultural Industries Ltd. for permission to publish this paper and to the following firms for information on the use of "PhoSAI" and permission to publish photographs of their products:-
The Cannock Agricultural Co. Ltd., Staffordshire.
The North Eastern Agricultural Co-operative Society Ltd., Aberdeen.
The Farmers Fertiliser Co. Ltd., Royston, Hertfordshire.
Edward Webb & Sons (Stourbridge) Ltd., Worcestershire.
C. Wiles Ltd., Beverley, Yorkshire.

REFERENCES1. PATENT PROTECTION

Letters Patent have been applied for by Scottish Agricultural Industries Limited for both the process of manufacture and the subsequent use of S.A.I. ammonium phosphate in the U.K. and in overseas countries. The British Application Numbers are as follows:-

<u>British Application No.</u>	<u>Subject</u>
32399/61	Manufacture of Solid Ammonium Phosphate.
11466/63	Manufacture of Solid Ammonium Phosphate.
16960/63	Apparatus for the Manufacture of Solid Ammonium Phosphate.
32398/61	Manufacture of Granular Fertilisers.

2. I.S.M.A. PAPER

F.J. Harris: "The Incorporation of Ammonium Phosphates into Granular NPK Fertilisers".

I.S.M.A. Technical Meeting - Stockholm, 1959.

DISCUSSION

Dr. I. A. BROWNLEE (United Kingdom) : This paper reviews the work done on the development and use of a new form of monoammonium phosphate. Before dealing with the details of the paper, I should like to say that, prior to the manufacture by Scottish Agricultural Industries of ammonium phosphate, most of our products were based on superphosphate. We have had a very considerable business in supplying superphosphate to other manufacturers who use it to make compound fertilisers. Thus, we had to consider how to obtain a form of ammonium phosphate which would be suitable for use by these other companies. The work on this paper is really a continuation of work done by S.A.I. which was reviewed by Mr. Harris at the I.S.M.A. Technical Conference in Stockholm in 1959. At that time we had not yet found a way of making a powder product with good granulation properties for incorporation in granular NPK fertilisers. We then described a form of small granular monoammonium phosphate which we had found to be suitable and which was used by other companies. However, we continued the work and, in doing so, we bore in mind a number of conditions which had to be satisfied by the product. Firstly, the stage of conversion from phosphoric acid to the solid form of monoammonium phosphate should be a cheap one. Secondly, the material should be as concentrated as possible. Thirdly, it should be easily incorporated in granular fertilisers. Fourthly, it should store well; and lastly it should be capable of being transported in bulk and handled in conventional equipment.

We have now discovered a simple process for making monoammonium phosphate in powder form and the product is rather similar in appearance to superphosphate. The process is simple, and capital cost is low. The monoammonium phosphate produced contains about 6% moisture, which aids granulation when producing granular NPK compounds and results in a lower addition of steam or moisture during granulation. Furthermore, the NPK compounds themselves emerge with a lower moisture content prior to drying. These two factors result in economies in steam and fuel usage.

We believe the performance of the product to be superior to triple superphosphate and granular mono- and diammonium phosphates. In NPK compounds our product is compatible with urea and superphosphates. Many of the results reported in our paper were supplied to us by companies in the United Kingdom which use the material. You will find in Table 5 to 9 a list of figures which we have obtained through the kindness of these firms.

In order to give an idea of the amount of material we are now manufacturing, we should like to say that the production is of the order of tens of thousands of tons per annum.

We have found the product to have excellent storage properties, and it can be, and is being, transported in bulk by sea and by road transport throughout the U.K. Originally, we developed this material for use by a few companies in Scotland, but now it is being used throughout the U.K., and we believe that it is a suitable replacement for superphosphate in the general trend towards higher concentration. It is possible that phosphate rock producers wishing to solubilise their rock at source may find this to be a useful material to supply world markets.

Mr. K. C. KNUDSEN (Denmark) : The authors are to be congratulated on making a product of much higher concentration than superphosphate without losing its good granulation properties. It is claimed that this new product, when used as a source of P_2O_5 in NPK compounds, reduces the granulation moisture requirements, thus reducing the cost of steam and drying, as compared with other forms of ammonium phosphate. I should like to ask Dr. Brownlie to what extent it is found necessary to dry the resulting compounds.

The product in powder form is said to have excellent storage properties with moisture contents of between 6% and 12%, whereas it seems that when produced in granular form for use in bulk blending it is sold with a moisture content of

below 1%. Table IV indicates that the finished NPK products contain 0.1% to 0.6% moisture. On the basis of investigations carried out by Dr. Raistrick some years ago, S.A.I. formerly stated that superphosphate-based fertilisers should be dried to a moisture content of about 0.0% - 1.6% whilst ammonium phosphate-based fertilisers should be dried to about 0.2% moisture, so that both the former and the latter should have a relative humidity of below 30%. I should be interested to know whether this new product of S.A.I. resembles superphosphate or ammonium phosphate in this respect, because this may affect drying costs.

My next question concerns the cost of transporting the moisture content. The moisture content of your new monoammonium phosphate and other ammonium phosphates differ by 6 to 12%. Manufacturers buying your product as a raw material must pay for the transportation of this extra water. Have you calculated what distance you can transport your product before this extra transportation cost equals the savings in drying and steam raising costs? Naturally, in this connection, you have to take account of relative overall manufacturing costs as well.

Thirdly, your new product seems to promote the position of agglomeration processes as compared with slurry processes. I believe S.A.I. have experience of both methods. I should be interested to know whether you find it more profitable - all manufacturing costs considered - to make NPK compounds based on your new product rather than on a slurry process such as the Dorr process, or, perhaps, a nitro-phosphate process? The answer to this question could be of great importance for the future of your product.

Dr. BROWNLIE : The first question concerned the moisture content of granular NPK compounds. In this connection I should explain that the figures of 0.1% to 0.6% mentioned in Table IV refer to some short-term experimental trials we carried out ourselves at the beginning of the project. These trials related to the production of products based purely on ammonium phosphate. The later tables refer to results from some of our customers who make products containing not only ammonium phosphate but also superphosphate and, in some cases, urea and

other materials. But when you are considering a product made from this new form of monoammonium phosphate, it is not likely that the moisture content of the finished NPK compound will be any different from that obtained by using any other form of monoammonium phosphate. Chemically speaking, it is not likely to have any effect on the desired moisture content of the product.

The second question referred to the economics of the transport of the material. There is no doubt that, where long distances are involved you would have to take the extra moisture content of our new product into account; but at present we are supplying the material competitively over a range of 400 - 500 miles. In the final analysis, what really matters is the price at which you can supply each unit of plant nutrients; so that one has to consider the transport costs together with the whole range of manufacturing costs. I have little doubt that when this is done, the result is favourable to the new S.A.I. product.

The third question related to the respective merits of the slurry process and the agglomeration process. It is true that S.A.I. have based their products in the past on the slurry process and have built up a lot of experience of it. The first point to bear in mind is that we already have slurry plants. In any debate on the two processes, we should naturally have to take into account the capital we have already spent and the life of the plant acquired. In a process for making compound fertilisers, you may not want to go through the intermediate solid stage if you have phosphoric acid available, but, if one was starting from scratch, I would not like to say definitely which was the better process to adopt.

Mr. H. C. KIDD (United Kingdom) : There is little doubt that the development of this new S.A.I. process and, more particularly the product itself represents a considerable advance in fertiliser technology. I should like to ask Dr. Brownlie a number of questions. Firstly, with regard to Table 1, page 4, I gather that materials of varying analysis are, or will be, available, containing varying proportions

of ammonium sulphate. Do these materials have the same characteristics, particularly with regard to granulation and storage ?

Secondly, I should like to refer to a statement on page 17, which mentions a water requirement of 0.4 - 0.5 tons per ton of P_2O_5 for granulating the material alone. Considering the high concentration of P_2O_5 in the product, this seems to be rather a high water requirement, and beyond that quoted for achieving the thixotropic state. Are we to assume from this that the physical agitation resulting from granulation is insufficient to soften the material at its critical moisture content ?

Dr. BROWNLIE : With regard to Mr. Kidd's first question, Table 1 is an extract from a table which is in one of our patent applications. I believe this patent specification has already been published in Belgium. We have quoted figures for ammonium sulphate in the paper, but we also have figures for ammonium nitrate which were included in the patent, our object being to cover a range of materials. Most of these results are from laboratory tests, and it is therefore somewhat difficult to say at present how they would emerge on a large scale. But I think you might say that as the proportion of ammonium phosphate decreases, the beneficial effect on granulation properties would also decrease. Similarly, there is some effect on storage characteristics as the proportion of ammonium sulphate increases.

With regard to the amount of water required in granulating our ammonium phosphate, the result which Mr. Kidd quotes is taken from a short run on one of our own plants. I did not think myself, that the water requirement was unduly high. The granulation characteristics do not involve any great softening of the product whilst granulation takes place. The quoted value of 0.4 to 0.5 tons of water per ton of P_2O_5 takes into account the amount of recycle material required in the granulation process.

Mr. B. CARLSEN (Denmark) : We understand that the method of manufacture cannot be revealed in this paper, as it is the subject of patent applications. It is, however, stated that it is basically as simple as the original superphosphate process. Would it be too frank to ask whether it can be produced in a normal superphosphate

plant and, more specifically, in a Broadfield plant, with small modifications :

Dr. BROWNLIE : I think the answer to that question must be "Yes, it would be too frank ..."

Mr. R. ARDQUIN (France) : The process described by the authors, as well as their explanation of the influence of the thixotropy of the monoammonium phosphate slurry on granulation, is very interesting. But the product can only be of interest to compound fertiliser producers if the units of N and P_2O_5 are at an equivalent or cheaper cost price than in triple superphosphate and ammonium nitrate. This product cannot be used in formulations where a high proportion of nitrate nitrogen is required, as in France, and hence its success in the United Kingdom where ammoniacal nitrogen predominates and the nitrate form of nitrogen is little used.

Dr. BROWNLIE : I would agree with that.

Mr. E. W. SCHWEHR (United Kingdom) : In the paper the value of this material in granulation is based on formulations which quite obviously contain considerable quantities of superphosphate in addition. Could Dr. Brownlie confirm that his new material is still as advantageous as, for example, triple superphosphate in the granulation process, when it is the sole source of P_2O_5 ? This is the point we shall reach as plant nutrient concentration increases. I can imagine this material being more beneficial than a small granular monoammonium phosphate, but is it as beneficial as triple super, when it is the sole source of P_2O_5 ?

With regard to the handling characteristics of Dr. Brownlie's material on plant equipment, I should be interested to know whether it flows as readily as comparable materials on conveyors, in chutes or in elevator boots.

In addition, I should like to confirm that, in general, the introduction of monoammonium phosphate as a replacement for triple and single superphosphate necessitates a decrease in the moisture content of the product in order to obtain the same storage characteristics. I think Dr. Raistrick's work on this subject remains an excellent yardstick as to the amount of moisture reduction required.

As far as the economics are concerned, I think this aspect has to be considered at all stages right through to the finished product; for while the P_2O_5 in the monoammonium phosphate must cost more than that in triple superphosphate (since all the P_2O_5 comes from acid), one is able to introduce cheaper forms of ammonia into compounds sold on a water soluble basis, as in the U.K.

Dr. BROWNLIE : S.A.I. does not manufacture triple superphosphate. Thus we have to rely on those firms which do manufacture or use it, in order to compare its granulation properties with those of monoammonium phosphate. So far, we have not found a firm which uses triple superphosphate as the sole source of P_2O_5 ; but we have compared it with monoammonium phosphate when other materials have been present, and the results, as given in the paper, are favourable to monoammonium phosphate. However, if Mr. Schwehr were to give us an opportunity of carrying out a direct test between the two materials, we should gladly take advantage of it.

With regard to handling characteristics, the first customer we had for this new monoammonium phosphate - a small firm in England - did indeed encounter handling difficulties. After visiting them, we were able to remedy their troubles; and so far, among our customers, there is not one whom we have not been able to help and who is not still using our material.

The third question related to the moisture content of the product when made from monoammonium phosphate, as compared with that when made from triple superphosphate. Again, we have not been able to carry out a direct comparison, but in the paper we mention a particular manufacturer who has made compounds from both triple super and monoammonium phosphate in the presence of other materials; and he has stated quite definitely that he can obtain better performance from our monoammonium phosphate. However, again we should be glad of an opportunity to make a direct comparison.
