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THE SAI-R PROCESS FOR THE MANUFACTURE OF COMPOUND
FERTILISERS CONTAINING AMMONIUM NITRATE
AND DIAMMONIUM PHOSPHATE

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INTRODUCTION

The continuing increase in the concentration of compound fertilisers has been achieved by the greater use of materials such as diammonium phosphate in place of superphosphate and either ammonium nitrate or urea in place of ammonium sulphate. The introduction of these new materials which are, in general, more soluble and more temperature sensitive has necessitated either the modification of existing methods or the development of new methods for producing the more advanced fertiliser products in an acceptable or preferably in an improved granular form.

GENERAL CONSIDERATIONS

The desirable features of a process designed specifically for granulating materials of this type can be indicated by a general consideration of the physical properties of the materials which it is required to handle. In this paper special attention is paid to diammonium phosphate and ammonium nitrate.

Diammonium phosphate is thermally unstable. It has a measurable partial pressure of ammonia at 80°C and above 100°C this pressure rises very rapidly. Therefore when processing diammonium phosphate it is desirable to restrict both the temperature of operation and the air volumes passed through the system. In this way ammonia losses from the system can be minimised. However a restriction on the temperature of operation throughout the system can, in practice, have disadvantages e.g. a reduction in the rate at which moisture is removed from the system, i.e. the drying rate of the material may be lowered significantly. Therefore larger driers operating at lower temperatures can be required.

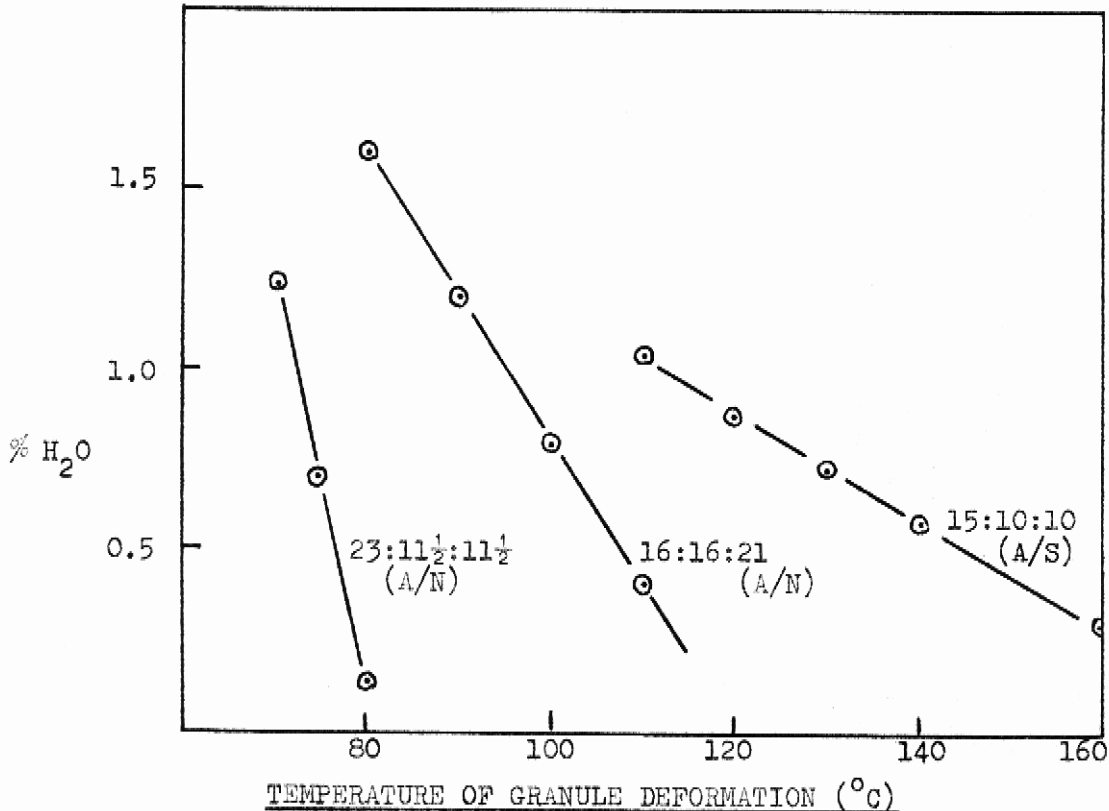
The principal differences in the properties of compound fertilisers containing ammonium nitrate from formulations which contain ammonium sulphate as the principal source of nitrogen are:-

1. At a given moisture content the materials soften or become plastic at lower temperatures (when dry 95° to 120°C as against 140° to 160°C).

2. The solubility of the materials and therefore the plasticity mentioned above are more dependent on temperature and therefore more rigid temperature control is necessary. (Fig. 1).

FIG.1

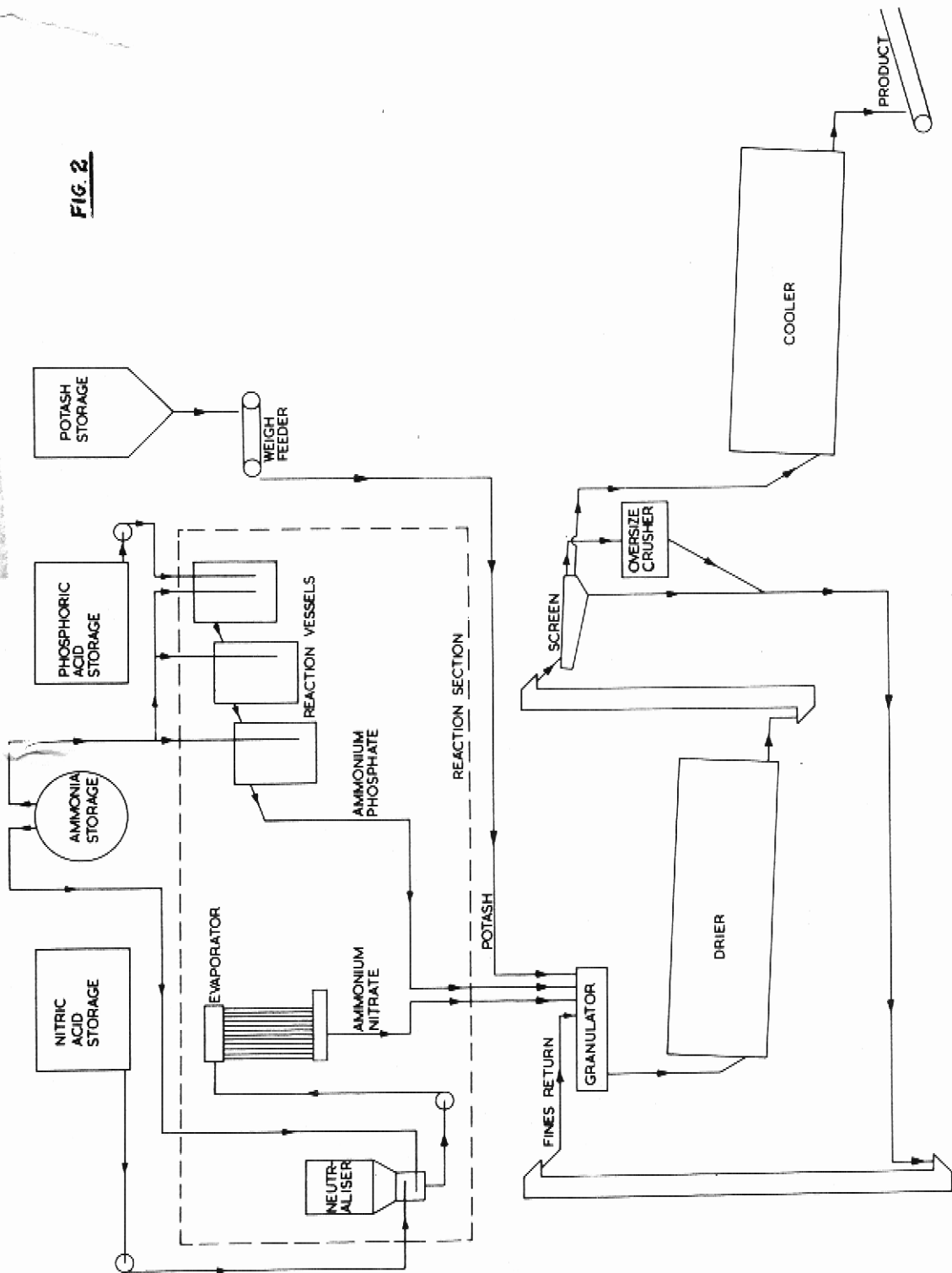
VARIATION OF TEMPERATURE OF GRANULE DEFORMATION WITH MOISTURE CONTENT



3. They are considerably more hygroscopic at ambient temperatures. (about 2½ to 4 times).
4. They are less thermally stable.
The sensitivity of the physical condition of these materials to moisture and temperature necessitates granulation being carried out at relatively low temperatures and low moisture levels if serious overgranulation is to be avoided.

In the usual granulation recycle processes (Fig. 2) this means that low moisture slurries are required in order to avoid very large recycling of dry solids back to the granulation stage. In practice some sort of balance is required between these two but, in general, limitations in the handling of low moisture slurries mean that relatively high recycle systems cannot be avoided. Another approach to the slurry handling problem is to do a partial pre-neutralisation followed by a final

FIG. 2



CONVENTIONAL GRANULATION PLANT FLOW DIAGRAM

neutralisation during the granulation stage.

The rapid change of solubility with temperature creates a further problem with conventional recycle systems since it necessitates extremely rigid control of both the temperature and quantity of the solids being recycled to the granulation stage.

The observation that formulations containing ammonium nitrate are considerably more hygroscopic is simply a reflection of the very low water vapour pressure above these solids so that it is difficult to dry them.

It is well known that granulation by the normal techniques involves agglomeration and although this can be reduced by increasing the recycling of solids it remains the most significant mechanism for granule growth in most slurry-recycle processes. Granule growth by agglomeration means that smaller particles are brought together and held in that form by solutions of the more soluble salts which ultimately crystallize as the material is dried. Therefore for granules to dry which are formed in this way moisture which is inside the granules must diffuse to the surface before it can be evaporated. As the moisture evaporates the solids are deposited at the surface and can restrict or prevent further diffusion and evaporation. Higher temperatures may emphasise this problem since more solids will be in the solution which is carried to the surface and indeed since there may be a tendency for surface fusion to occur.

The thermal instability of ammonium nitrate is well known. When heated beyond a certain temperature, say 150°C , it decomposes and the decomposition can be catalysed by the presence of chloride. During decomposition acids are formed which further catalyse and accelerate the decomposition. This particular aspect of decomposition can be minimised by neutralising any acid as soon as it is formed and in compound fertilisers a suitable source of ammonia for neutralisation is diammonium phosphate. We have found that to have this material in intimate contact with ammonium nitrate does minimise the tendency for decomposition.

Having considered some of the relevant properties of the materials which must be handled, the features which seem to be desirable in a process for making concentrated fertiliser which contain a high proportion of ammonium nitrate are:-

1. Granulation at low and controlled temperatures because of thermal instability and solubility effects.
2. Granulation at low moisture levels to avoid overgranulation and to minimise external recycling of solids.
3. Drying at low temperatures with the minimum of thermal gradients because of solubility effects and thermal instability.

4. The production of diammonium phosphate in intimate contact with ammonium nitrate to enhance stability.

SAI-R PROCESS

In following the trend to higher concentration our Company, Scottish Agricultural Industries Ltd., chose for a new nitrogen source ammonium nitrate to replace ammonium sulphate which had been the main nitrogen carrier in ammonium phosphate compounds of the following formulations:-

12:12:18, $13\frac{1}{2}:13\frac{1}{2}:13\frac{1}{2}$, 12:24:12, 15:10:10.

When ammonium nitrate had been chosen our agronomists told us that we must be able to produce a high analysis 2:1:1: NPK grade. Trials were carried out on the pilot plant scale of two well known processes. The difficulties revealed by these trials suggested that an entirely new approach was worthy of consideration. Some small scale trials had already been conducted on what developed eventually as the SAI-R process and it was decided to build a pilot unit capable of production rates of from one to two tons per hour. On this unit about 3,000 tons of a variety of grades were produced for testing both on the land and in large scale bag and bulk storage conditions. As a result of this study we were convinced that this process had considerable practical advantages, both in the manufacture of the fertilisers and in the quality of product which it produced.

Before considering the process in detail a consideration of its salient features indicates how much the properties of the materials which were discussed earlier have influenced the principles adopted in the process.

1. Reaction, granulation and drying are carried out in one unit.
2. The complete drying of the product is achieved by use only of the heat from chemical reactions. This means that by a suitable choice of acid concentrations there is sufficient heat from reaction with ammonia to drive off all the water present and give a dry product.
3. Solids are recirculated at extremely high rates within the unit. This both minimises the possibility of thermal gradients and allows the addition of the acids direct with the complete elimination of reaction vessels for the pre-neutralisation of phosphoric and nitric acids and so the avoidance of slurries.
4. The high solid recirculation rates allows granulation to be achieved principally by a layering mechanism rather than by agglomeration. Therefore granulation can be achieved at lower moisture levels and drying obtained with the minimum influence from diffusion resistance from within the granules. In other words drying can be achieved

essentially by a surface mechanism and the heat from the chemical reactions is released at the surface where it is required.

5. A distinct zone with a restricted air flow to increase the ammoniation efficiency during the formation of diammonium phosphate.
6. Ammonium nitrate and diammonium phosphate are produced in intimate contact so that thermal instability is minimised and in addition, ammonium nitrate as such need never be handled.

If we now consider the process in detail then the basis of the SAI-R process is the efficient utilisation of the heats of reaction of ammonia with phosphoric and nitric acids to evaporate the associated water and produce a dry granular material.

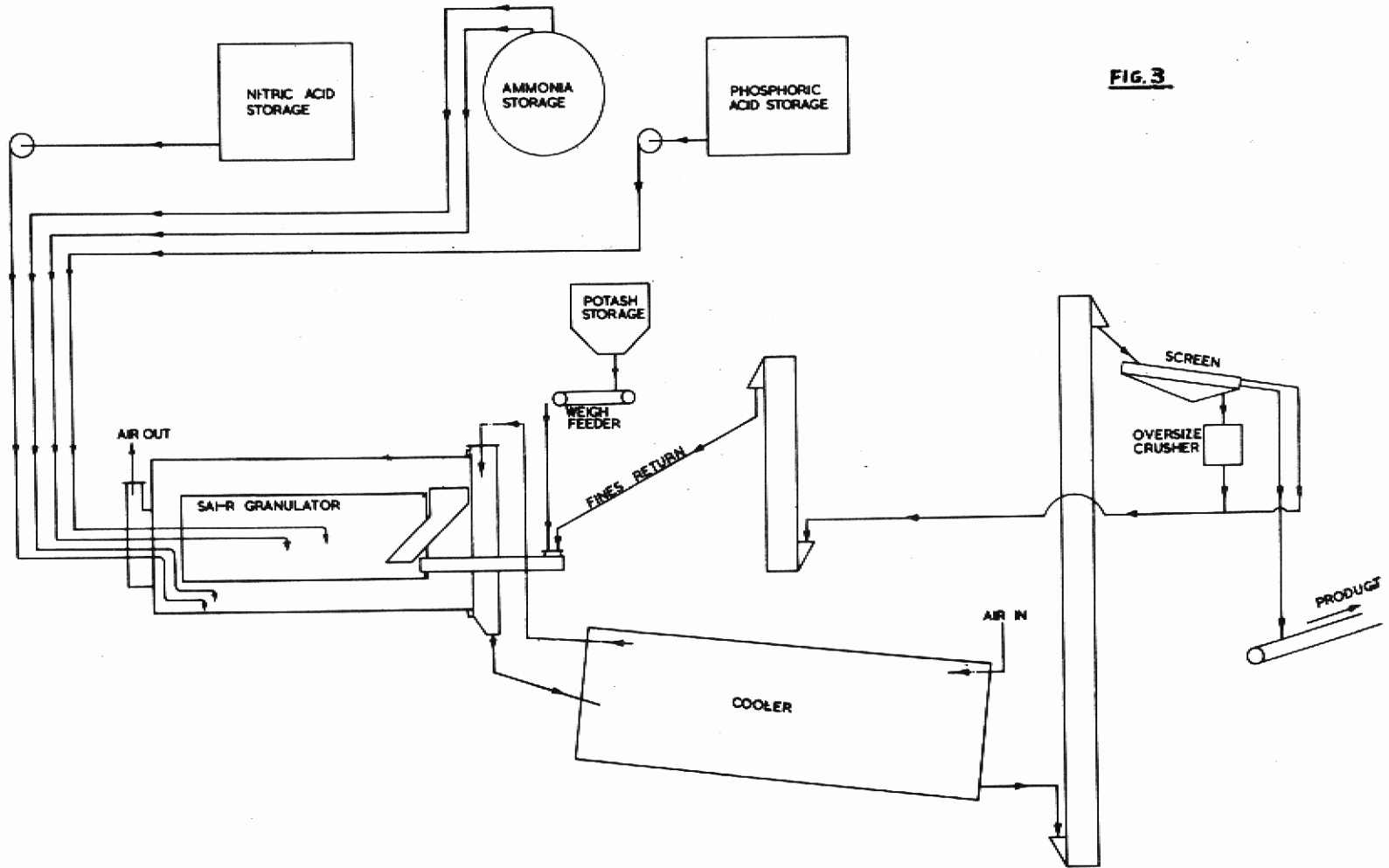
A general solids flow diagram of a granulation plant based on the SAI-R process (Fig. 3) has one significant difference from more conventional plants in that reaction granulation and drying take place in one unit. A consideration of the process therefore means a consideration of the granular unit itself although as will be seen later some of the functions of the basic ancillary equipment are also influenced by features of the process.

The granulator (Fig. 4) consists of a rotating unit of two concentric drums with the solids progressing along the outer drum, being elevated via buckets, hopper and chute into the inner drum and being displaced along the inner drum until they spill over and out into the outer drum again. Thus are achieved the high rates of solid recirculation which are desirable to ensure surface reaction and drying; in a large scale production unit this rate is about 600 tons per hour.

Air is drawn through the outer drum in a direction countercurrent to the movement of solids in that drum. The air movement through the inner drum is restricted since the only inlet is through the chute carrying the solids and so the minimum usage of air can be achieved in an ammoniating zone to minimise ammonia losses. Therefore this inner drum is used for the formation of diammonium phosphate by distributing phosphoric acid on the rapidly moving granular bed and injecting gaseous or liquid ammonia under the bed of acidified granules.

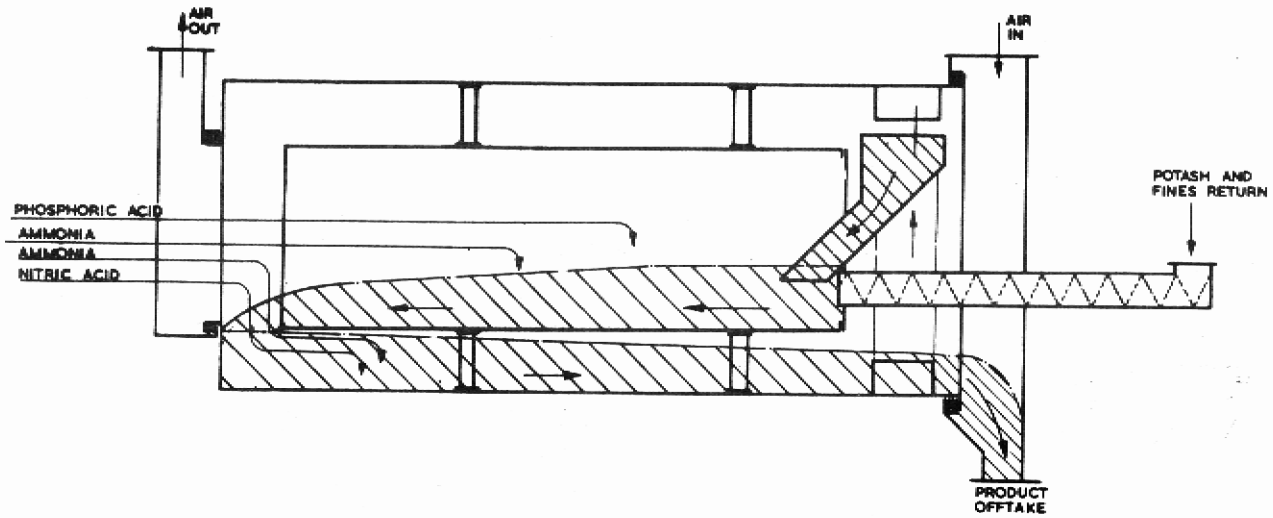
The conditions of minimum draughting mentioned for diammonium phosphate production are not so necessary for the efficient formation of ammonium nitrate. Hence nitric acid is distributed and ammoniated in a similar manner in the moving granular bed in the outer drum and subjected to a sufficient volume of countercurrent air to ensure that the solids having passed along the outer drum may enter the inner drum as virtually dry material to commence the cycle again.

FIG. 3



SAI-R GRANULATION PLANT FLOW DIAGRAM

FIG. 4



SAI INTERNAL RECYCLE PROCESS

The only solid raw material which need be incorporated to give a complete NPK fertiliser is muriate of potash. The point of introduction of this material in the cycle is governed by the relative rates of its chemical reaction with the various acid feeds in the system. Since the reaction with nitric acid is extremely vigorous contact of the muriate of potash with nitric acid must be at least minimised if not avoided. However the reaction with phosphoric acid is relatively slow at the temperatures obtaining in the system and so it is preferable to introduce the potash to the cycle at a point just before the addition of the phosphoric acid. In this way it has the opportunity to become incorporated in the ammonium phosphate before coming to that part of the cycle where the nitric acid is introduced.

It is at the lifting end of the outer drum that the material is at its lowest moisture level and so it is at this point that the material is removed for size grading and extraction of product.

It is from this removal point at the granulator that the process follows conventional lines of cooling, screening, oversize cracking and recycle of fines and cracked oversize to the granulators. This returning material enters along with the potash into the inner drum of the unit and so again has the opportunity to become incorporated before entering the air stream in the outer drum.

A large scale production unit based on the SAI-R process is now in operation at our Leith Fertiliser Works and some practical data from this plant illustrate the various factors which have been discussed earlier.

There are two granulator units each 15' diameter and about 36' long rotating at 14 r.p.m. Operation at the relatively high speed of rotation (about 70% of critical speed for the outer shell) is simplified by mounting the units on pneumatic tyres. (Fig. 5).

There are no reaction vessels and no slurry handling in the process and, with the exception of muriate of potash, all raw materials are metered into the plant as gases and liquids. (Fig. 6).

The internal solids recirculation ratio varies with the formulation being processed but is generally in the range of 40:1 to 70:1.

The acid concentrations which are required depend both on the formulations and on the extent of ammoniation of the phosphoric acid. For example phosphoric acid of 41% to 43% P_2O_5 is used with high potash formulations such as 16:16:21 and in the range of 47% to 49% P_2O_5 for high nitrogen formulations such as 23:11½:11½. The nitric acid supplied by a Kuhlmann plant is 69% NHO_3 and it is our practice to use it at this

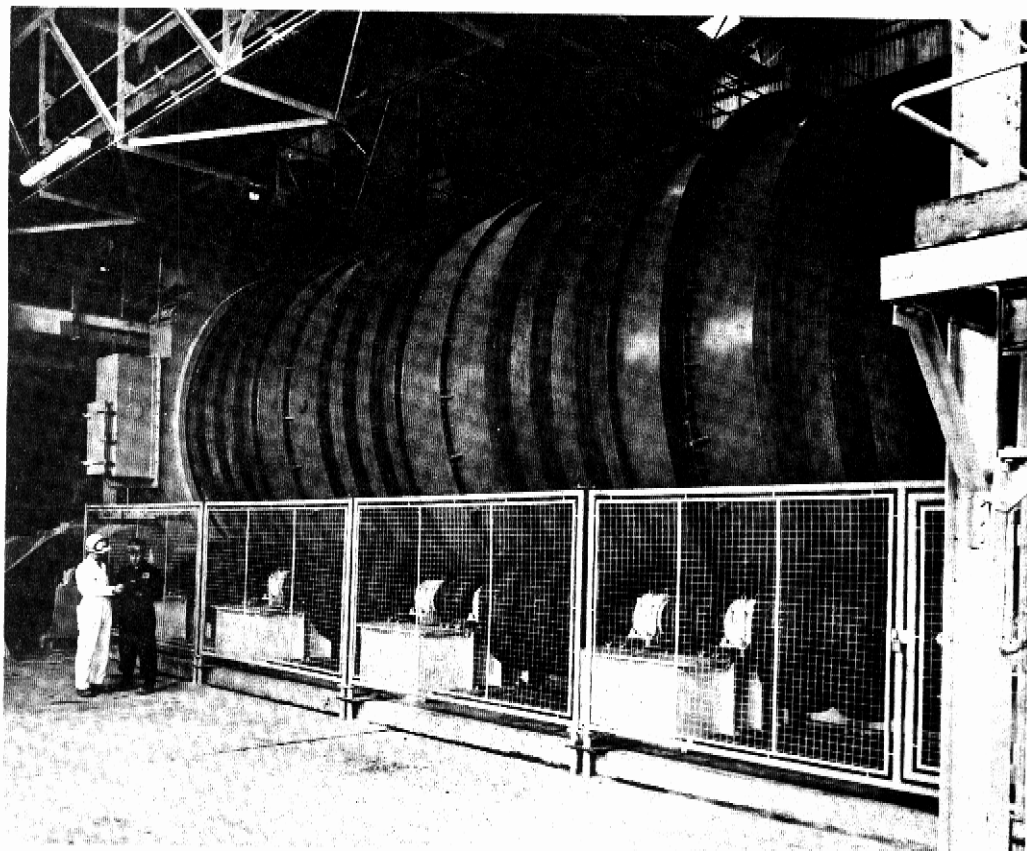


Fig.5 : Photograph of large scale granulator

concentration. Any water required for balancing heat evolution may be supplied by incorporating a proportion of filtrate strength phosphoric acid in the phosphoric acid stream.

The effluent gases from the granulators contain small quantities of ammonia as well as dust and moisture. This may be subjected to acidified scrubbing before discharge to the atmosphere.

The operating temperatures have been in the range of 75°C to 100°C depending again on the formulation being processed and the maximum temperature gradient in the solids within the granulators has been 1°C to 3°C . The moisture level of the products generally has been about 0.3% to 0.5% as determined by the Karl Fische method.

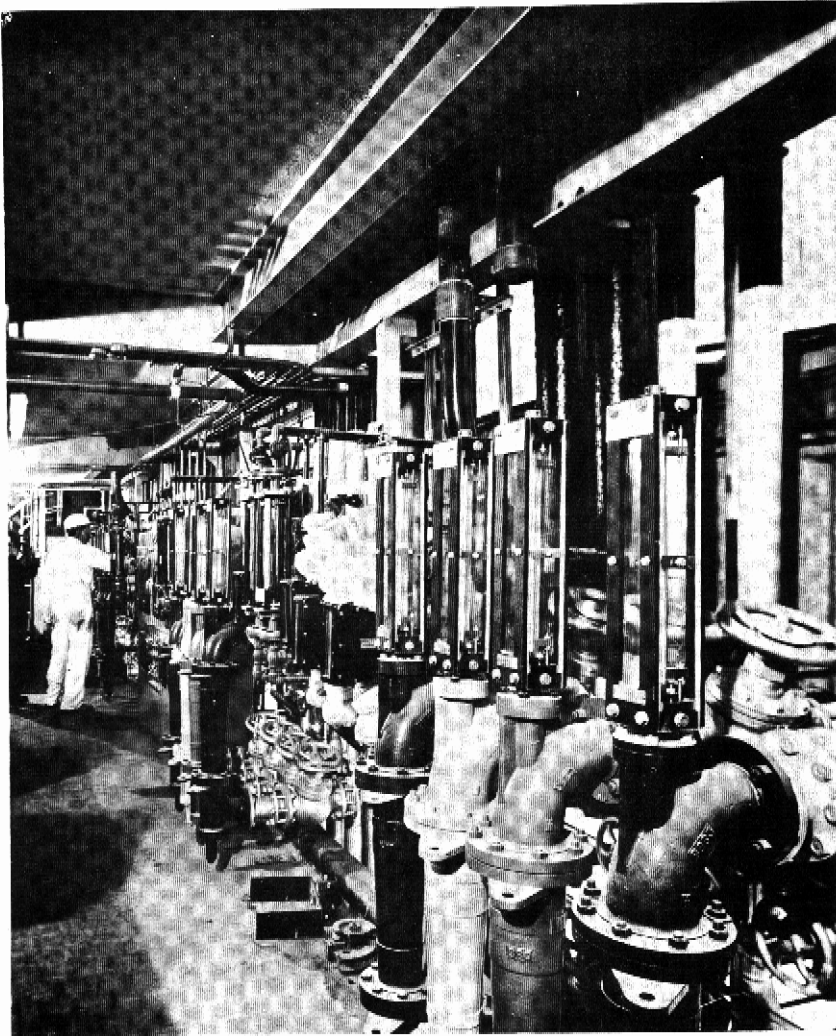


Fig.6 : Photograph of control room floor with metering systems

The plant at Leith Fertiliser Works is designed to produce a number of formulations, the total tonnage depending upon the relative proportions of the various formulations since the production rates can vary significantly.

Since granulation is achieved by layering in preference to agglomeration the granules are extremely dense, hard, round and smooth surfaced. (Fig. 7). These advantages of the products are shown in practice as:-

- (i) Bulk densities some 15% greater.

- (ii) Granule crushing strengths some 50% greater.
- (iii) Improved storage properties evidenced by the necessity for reduced quantities of conditioning agents.

The process yields extremely uniform granulation and the discharge from the granulator normally contains greater than 70% product size material. (Fig. 8). The principal advantage of this is the small amount of oversize material which it is required to crush for reprocessing since this can be a serious problem with materials of a plastic nature.

In conclusion the merits of this process may be summarised as:-

1. The elimination of external reaction vessels and slurry handling.
2. The reduction of thermal and moisture gradients to a minimum.
3. The increased simplicity of control both of feed materials and granulation.
4. A product of significantly superior quality.
5. Safer working conditions since ammonium nitrate as such need never be handled and heat from an external source need never be applied.

ACKNOWLEDGEMENT

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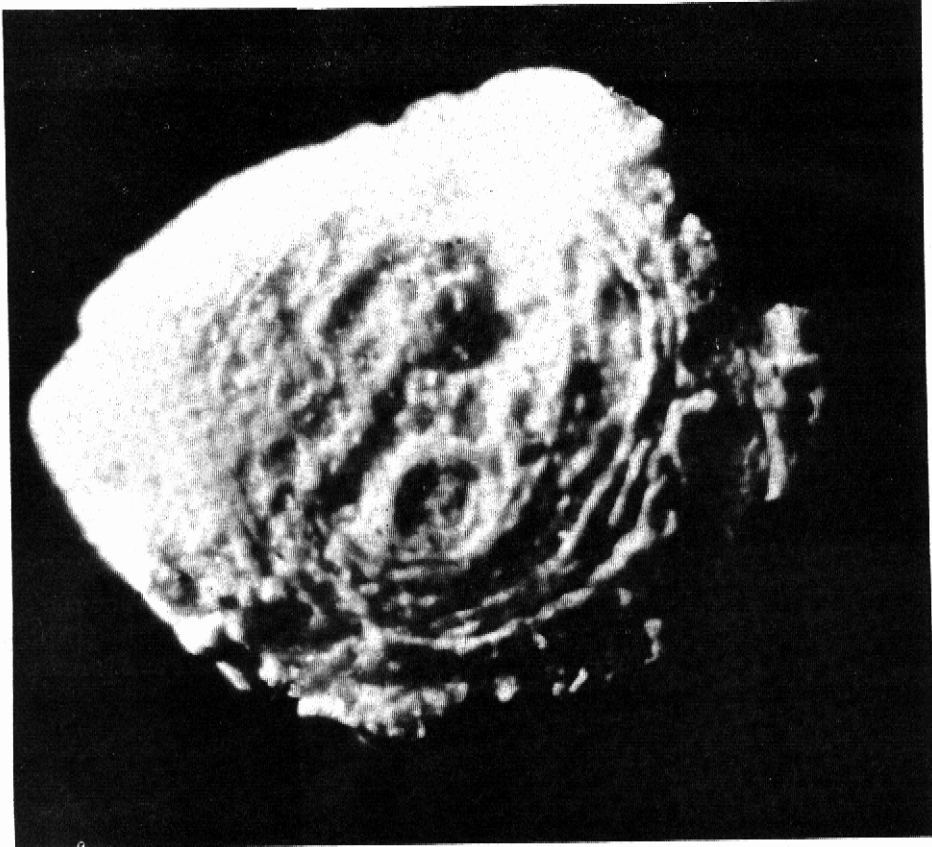


Fig.7
Section of
granule
Tranche d'u
granule



Fig.8
Granulator
discharge
conveyor
Courroie de
débit du
granulateur

DISCUSSION

Mr. J. W. BAYNHAM (Scottish Agricultural Industries Ltd., U.K.):

As in the case of the processes described in previous papers presented to this conference, the process described in our paper also has an autothermal basis. I believe we have carried the principle somewhat further, in that we obtain a dry product directly from the process without any additional drying or any additional source of heat whatsoever. By a "dry" product I mean something with a moisture content of less than 0.5%.

The SAI-R process for the production of granular fertiliser materials has been developed and designed to handle the more temperature- and moisture-sensitive materials such as diammonium phosphate and ammonium nitrate, and so to produce high-analysis NPK fertilisers. The properties of such materials have already influenced many of the features of the process. In discussing it, one is considering primarily a single unit - the SAI-R granulator. This is a rotating unit of two concentric drums. The granular material within it may be recirculated at extremely high rates. In one region of it, conditions may be optimised for the formation of diammonium phosphate. In short, therefore, the main recycle of the process is contained within one unit. Only a subsidiary external recycle is necessary for size-grading and removal of product, etc.

Reaction, granulation and drying are carried out in the one unit. The complete drying of the product is achieved only by means of the heat derived from the chemical reactions. Thus, by a suitable choice of acid concentrations - phosphoric and nitric - there is sufficient heat from reaction with ammonia to drive off all the water present. The extremely high solids recirculation rates both minimise the possibility of thermal gradients (which is very important in dealing with formulations containing high percentages of ammonium nitrate) and allow the direct addition of the acids, with the complete elimination of reaction vessels for the pre-neutralisation of the phosphoric and nitric acids. It therefore also avoids any handling of slurries.

Again the high solids recirculation rates allow granulation to be achieved principally by a layering mechanism, rather than by agglomeration. This means that granulation can be achieved at lower moisture levels, and the drying can be obtained with the minimum influence from diffusion resistance from within the granules. In other words, one obtains remarkably rapid drying for this type of material.

The drying is achieved essentially by a surface mechanism. The heat from the chemical reaction is released at that surface, just where it is required.

A further feature is a distinct zone for a restricted air flow, in order to increase the ammoniation efficiency during the formation of diammonium phosphate.

The ammonium nitrate and diammonium phosphate are produced in intimate contact within the one unit. The thermal instability of the products seems to be minimised in this way, and the ammonium nitrate as such is never handled.

With regard to the advantages offered by the produce of the process, bulk densities are about 15% greater than average, i.e. approximately 65 lbs/ft³. The granule crushing strength is about 50% greater than other products, and virtually no attrition occurs in handling. Finally, because the granules are built up by thin coatings, they are dense, very round and with a very smooth surface. This gives improved storage properties which is evidenced by the reduced need for conditioning agents.

Mr. Y. BERQUIN (Potasse & Engrais Chimiques, France) : The process described in the paper deals with the preparation of a type of solid fertiliser, the importance of which is growing daily in the world market. I refer to high-analysis compound fertilisers. Mr. Baynham has expertly highlighted the delicate features of this type of manufacture: very narrow temperature range between drying and softening for formulations with a high proportion of ammonium nitrate; thermal instability of the various constituents; plasticity; etc. We were particularly attracted by the idea of the division of labour between the preparation of layers of ammonium nitrate in optimum thermal conditions and their envelopment in layers of ammonium phosphate prepared similarly in optimum, though different conditions.

However, I should like to clarify certain points. Firstly, with regard to the problem of encrustation of the plant: I assume that, despite the precautions taken and as is always the rule in this type of manufacture, one must periodically shut down the plant for cleaning. Could you indicate the frequency and extent of cleaning? Also, does not the very structure of the unit, i.e. a double cylinder with accompanying cross-pieces, complicate this cleaning, particularly that of the external cylinder where the ammonium nitrate is prepared?

This question of the structure of the unit also seems to raise the problem of the distribution of the fluids in each of the two cylinders. You do, indeed, say that the phosphoric and nitric acids are distributed on the beds and that the ammonia is injected into the beds. Could you give us some details of the means by which these materials are fed into each of the cylinders?

You also recall the fire-damping properties of ammonium phosphate and its application to fertilisers containing ammonium nitrate. But can the increase in the temperature of the point of decomposition, which, I think, is the main effect of adding ammonium phosphate, operate fully in the present case, since, properly speaking, there is no intimate mixture of the two nitrate and phosphate constituents, but rather a juxtaposition of successive layers of practically pure salts?

Again, it is often admitted that the double decomposition which occurs between ammonium nitrate and potassium chloride is favourable to the thermal stability of the product, provided that the necessary conditions for a subsequent reversal of the reaction do not occur, i.e. that there is no subsequent presence of water. Is it not preferable to obtain this reaction, and does not the process you describe, in its application to NPK ternaries, prevent this beneficial effect?

Does not the large recycle you mention involve considerable energy consumption? Would it be possible to have an idea of this energy consumption, e.g. per ton of product?

We have greatly admired the way in which optimum conditions have been arranged for the ammonium phosphate phase of manufacture. We should be interested to know what is the maximum level of ammoniation of the phosphoric acid which you can thus obtain without excessive ammonia losses.

My last question concerns the tail end of the unit. One can see from the diagram that the circulating bed in the external drum is divided into two streams at its exit. A small proportion leaves the unit and enters the classical circuits: cooling, screening etc. But according to the indicated rates of internal recycle, the major part is directly re-introduced into the central cylinder. Is there a means of granule selection to direct the material to one or the other stream, e.g. as a function of granule size, and, if not, is there not a risk that certain granules will be imprisoned in the internal circuits and will grow increasingly large eventually preventing their normal extraction from the unit?

Mr. BAYNHAM: The granulator unit does have to be cleaned, particularly within the reaction zones, but there is a reciprocating scraper within the unit, which serves to keep the shells of the drums clean. The frequency of cleaning depends largely on what formulation is being produced and on the degree of operational control. As to the structure of the apparatus complicating the cleaning, I do not think the cleaning process is at all complicated. One might think that with one drum inside another there is a very cramped space between the two, but one has to remember the dimensions of the units. The outer drum has a diameter of 15 ft. and the inner drum, 9 ft., giving an annular space of 3 ft. between the two.

With regard to the thermal stability of the compounds, I think it is true that in an ideal system one might have discrete, individual layers of ammonium nitrate and ammonium phosphate in the granules; but in practice this does not really occur. We have x-rayed all the compounds we have produced, and we have always found that any possible chemical reactions have always occurred to completion in the product before it leaves the process. I think this answers this question, as well as the one relating to the double decomposition of ammonium nitrate and potassium chloride.

It would be foolish to deny that our high recycle rates

require much power; but I think one must remember that all the recycle is carried out within one unit : it is not transported around a large, external recycle system. In addition, we make full use of the heats of chemical reaction; so that when everything is taken into account, the total energy requirements for the process are certainly no greater than those for other comparable processes.

It has been our practice to make products with an N : P ratio of 1.6 in the ammonium phosphate component. We have not attempted to go any higher, either previously or in this particular process.

I cannot give details of the granule selection process from the unit to the external system, but it does not involve anything particularly complicated. It is essentially a random selection, and in our experience we have not had granules trapped inside the unit until they become excessively large. They emerge within the average granule size range.

Mr. M. DETUNCQ (Péchiney-St.Gobain, France): What is your present production capacity for a given formulation and is it possible to envisage larger unit capacities?

What are the contents of ammonia, dust and water in the effluents, and what acid do you use to recover the ammonia?

How do you effect a changeover from one formulation to another and how do you start up the system?

Mr. BAYNHAM: In our plant at Leith we have two units operating in parallel. Its capacity for making a formulation such as 16-16-21 is about 30 t/h or a little more.

The gaseous effluent from the process does contain some NH_3 , dust and water. It can be scrubbed to recover both the gas and solid plant food contents of the effluent, and these can be fed back to the process, whilst the water is, of course, discharged to the chimney as steam.

The only time external heat is applied is when starting up the unit. We charge the plant with the granular material, heat it up with hot gas to about the operating temperature, which depends on the formulation to be produced, and then bring on the feeds and cut out the external source of heat.

As far as changing from one formulation to another is concerned, there is obviously a certain amount of know-how in this, but there is no particular magic. With this process, one has a remarkable control of moisture and temperature levels within the system, and this helps in changing over from one formulation to another.

With regard to the maximum production capacity of a single-stream unit using our process, I had better call on one of my colleagues to reply to this.

Mr. J.P.A. MACDONALD (Scottish Agricultural Industries Ltd., U.K.): As has been explained, the present plant uses two drums to give the output we require. We chose two drums because we felt that, at the stage of development reached two years ago, it would be unwise to go to any larger scale. Moreover, there is a difficulty in transporting drums of this size - or larger - from the point of their manufacture to the point of installation. However, if that particular problem can be overcome - and we think it can - we believe these units can be made considerably larger to give roughly double the output of each unit at present in operation. But I must emphasise that the particular location of a fertiliser factory and the difficulty of moving the equipment from the point of manufacture in the engineering works may considerably affect the decision as to the size of unit to install.

Mr. N. KOLMEYER (Windmill Fertilizer Works, Holland) : The paper limits itself to high-grade formulations based on ammonium phosphate and ammonium nitrate. I believe your method of granulation might also be useful for grades lower in plant food content and prepared, for example, from nitric acidulation of phosphate rock. In this case, reaction vessels would be required, but it still seems possible to profit from the advantages of the procedure which you describe. May I have your opinion, Mr. Baynham, on this point?

I should also like to ask whether you have tried preparing granular DAP as such, and, if so, whether it was successful.

Mr. BAYNHAM: The priorities in our development work on this process have not so far permitted the complete investigation of nitro-phosphate production, and we have not so far offered this process for this type of product. However, I have no reason to disagree with your view that there may be an advantageous application for the principles of our process in the manufacture of nitrophosphate products.

We have attempted to make granular DAP in our pilot unit but not on the full scale. On the pilot scale, however, this was probably the first product we made, and it was perfectly successful; but our commitments on the full scale have been for other products.

Mr. A.M. BRZOZOWSKI (Mathew Hall Engineering Ltd., U.K.) : I presume it is quite easy to add micro-nutrients to the fertilisers produced by this process, but I wonder if you would comment on the best methods of doing this. For example, can micro-nutrient materials be added to the muriate of potash and form part of the granule, or would coating be preferable?

Mr. BAYNHAM: I see no reason why micro-nutrients cannot be added to the fertiliser produced by this process. They should be incorporated. We have found a remarkably uniform analysis throughout the granule size range. We have taken different cuts within the size range and obtain

the same NPK analysis in all cases. This could be a distinct advantage in achieving good distribution of micro-nutrients, and this would be much better than adding them in the form of a coating which might become loosened from the granule surface in handling.

Mr. R. ARDOUIN (Union Française d'Engrais, France): How do you vary the internal rates of re-circulation? If you do this by varying the speed of rotation of the cylinder, you simultaneously affect the conditions of granulation.

If granulation is disturbed, what means do you have for re-establishing it? Similarly, the drying cannot be regulated in the same way as in a plant receiving an external source of heat.

Have you ever granulated with potassium chloride which has received an anti-caking agent?

Mr. BAYNHAM: The internal recycle is a characteristic of the particular unit, and as such it is not varied. This is not to say that it is not possible to vary it, but in general one establishes a particular internal recirculation rate and regards that as a characteristic of the unit.

In my experience, our control of granulation and drying is far better than in the case of the normal slurry and external recycle processes. It has to be, in order to handle this type of material containing high quantities of ammonium nitrate. Control of granulation can be by the usual methods of varying either moisture or temperature, but in this case principally by varying temperature, because of the temperature sensitivity of the materials involved.

We have no preference for potash either treated or untreated with an anti-caking agent. We take shiploads of potash as they come, and although it has been suggested that there are variations in granulation with KCl, we have not found it an embarrassment so far. In the first year of operation of this process, we have made over 100,000 tons of two rather sensitive formulations.

Mr. P. MORAILLON (Péchiney-St.Gobain, France): Have you encountered any corrosion problems caused by the addition of nitric acid, since the drum is of ordinary steel?

Mr. BAYNHAM: We have recently had the annual shut-down of the unit, and it was thoroughly examined by metallurgists; and there was no sign whatsoever of chemical corrosion. The shell gets a layer of material built up on it, which probably protects the mild steel.

Mr. W.C. WEBER (Dorr-Oliver Inc., U.S.A.): The conventional flow-sheet shown in the paper is rather obsolete, at least according to present U.S. standards. It is now quite customary to use pre-neutralisation in a single saturated tank and then pump the slurry to a granulator. The ammoniation is then completed in the granulator.

One can then ammoniate in the pre-neutraliser to the point of maximum solubility, which for DAP is in the range of 1.35 - 1.40 mol ratio. One can obtain an 86% solids slurry in this way, whereas if ammoniation to DAP is completed with the older method, one would have to have a slurry of only about 75% solids. This is one way in which plant capacities have been greatly increased and drier loads, greatly decreased.

Could you tell us how much external recycle you have, e.g. in tons per ton of product, over the screens and pulverisers?

What is the size of the motor driving this double drum granulator?

Do you have any other pending installations?

Mr. BAYNHAM: We have spliced our two granulator units into our previous Dorr-Oliver granulation plant and we have used the external system existing for that. We have not studied this end of the system on the full scale. The external recycle has varied somewhat, approximately within the range of 2 - 5 :1, but I am certainly not saying that this was necessary. It was simply convenient to use what we had already got.

The motor used to drive the granulator unit is 750 h.p.

At the moment we have no other such units under construction, but our company has obviously shown a great deal of confidence in the process in turning its main factory over to it.

Mr. M.C. GOODMAN (Humphreys & Glasgow Ltd., U.K.) : To what extent is the process applicable to a lower strength of nitric acid, particularly when 50% P_2O_5 phosphoric acid is available? Could the process be adopted by pre-heating the feedstocks or by continuation of the start-up external heat circuit?

Mr. BAYNHAM: Yes, I believe the system could be modified as suggested by you. We have added external heat in our pilot plant; but we have not used weaker nitric acid on the full scale. We have a Kuhlmann nitric acid plant at Leith, producing 69% HNO_3 , and we have taken it at this strength.
