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THE MANUFACTURE OF GRANULAR COMPOUND FERTILIZERS
BASED ON UREA AS THE PRINCIPAL SOURCE OF NITROGEN

By

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INTRODUCTION.

The erection of large ammonia and urea fertilizer complexes, frequently close to the source of material feedstocks, has created a situation during the last decade where urea has offered considerable attraction as an easily handleable, safe and cheap form of nitrogen for straight application.

World urea capacity increased by an average rate of 67 per cent per annum from 1,600,000 tonnes nitrogen in 1962 to over 10,500,000 tonnes nitrogen in 1970. Whilst the highest regional expansion rate for urea has taken place in Eastern Europe, Asia remains the largest urea producing region in the world (Appendix I). In this region, Japan and India account for the major producing capacity.

World output of urea for fertilizer purposes accounts for 22 per cent of total fertilizer nitrogen output. China, India, USA, USSR are the major consumers with more than 50 per cent of the total world fertilizer consumption. Some 75 per cent of the Indian nitrogen fertilizer consumption is provided by urea.

It is expected that by 1979-80 the world fertilizer urea demand will be around 15,000,000 tonnes nitrogen representing some 30 per cent of total fertilizer nitrogen demand.

At the present time, the vast bulk of Urea nitrogen is being applied as a straight fertilizer in the developing regions. However, as agricultural practice develops it is likely that urea will become more and more used as the main nitrogenous component in completely balanced NP and NPK granular fertilizers. The economies that result from this concept through the streamlining of manufacture, storage, handling, bagging, distribution and application procedures have been practised for many years in the major European nations where ammonium nitrate is the major nitrogenous intermediate.

The object of this Paper is to describe and review briefly the fundamental research, development and full

scale operation initiated by the Fertilizer Division of Fisons Limited on the manufacture of granular fertilizers with urea as the principal source of nitrogen.

GENERAL REVIEW.

Although urea is known to have been used in the manufacture of granular fertilizers for over fifteen years, until recently the nitrogen content from this source has been limited and used to supplement other nitrogen donors such as ammonium sulphate.

Work by Du Pont on superphosphate based systems using urea-ammonia solutions was reported in 1955². TVA reported the storage properties of certain USP grades made with urea-ammonia solution and postulated the mechanism of caking in 1958³. During this same year ICI applied for a patent concerned with the production of urea-single superphosphate (USP) grades up to a maximum level of 20 per cent in conventional granulation equipment⁴. A further contribution to the use of urea-ammonia solution in the manufacture of USP grades was presented to the Technical Meeting of ISMA in 1961⁵. Jewell⁶ was responsible for making an important and early contribution towards the understanding and quantification of the USP system. In this work, the effect of temperature on urea hydrolysis and loss of water soluble P_2O_5 , with recommendations for the operation of the drying stage and product storage conditions were clearly stated. The stickiness of the USP system in the granulation and drying stages was already known at this time, and at least three patents^{7,8,9} are known to refer to the importance of free acid neutralisation in minimising this effect.

During 1964, TVA initiated a considerable development including pilot plant work on the urea-ammonium phosphate (UAP) system¹⁰; a summary was reported to the ISMA joint Agricultural-Technical Conference at Stresa in 1967¹¹.

Gupta and Rao reported laboratory scale tests on a range of NPK grades based on superphosphate, urea, diammonium phosphate and potash in 1969¹². A loss of P_2O_5 water solubility stemming from the SSP-DAP reaction was noted. The sticky nature of urea-acidic superphosphate mixtures caused by the release of water of crystallization from the monocalcium phosphate was not experienced, this being also attributed to the reduction of the superphosphate free acidity by the presence of DAP¹³.

During 1968, FERTIBERIA operated a pan granulation unit to manufacture high analysis fertilizers based on MAP and SSP with up to 17 per cent urea. Some 40,000 tonnes of 12-12-24, 12-24-12 and 8-24-15 were made.

More recently, a number of the fertilizer manufacturers in the United Kingdom who have not had access to ammonium nitrate have been manufacturing high analysis fertilizer based on urea, ammonium sulphate, superphosphates, and/or ammonium phosphate. 20-10-10 is a typical grade requiring around 25 per cent urea. Prilled urea is generally used, occasionally with a light crushing to minimise the appearance of ungranulated prills in the product. Steam is used to promote granulation; this being completed in the drier. Ammoniation of the superphosphate content is not generally practised since water-soluble P_2O_5 has a premium in the UK market. A notable summary of UK practice was contained in a Paper offered for presentation to the proposed ISMA-FAI Technical Conference in 1971¹⁴.

Ando¹⁵ has recently summarized Japanese experience. In 1968, approximately 99,000 tpa urea was used in the production of granular NPK fertilizers, compared with 152,000 tpa ammonium sulphate and 4,000 tpa ammonium nitrate. The most important grades containing urea are 17-17-17, 16-16-16, 15-15-15, 10-20-20, and 20-20-14. These grades are manufactured in conventional rotary drum and pan granulation units. Lightly crushed or crystalline material is used as a feed stock. Urea melts are being used in some plants. Ammonium phosphate is added as a powder intermediate* (e.g. Fisons MINIFOS) or a slurry.

In 1970, TVA announced its intention to erect a full-scale demonstration plant for the manufacture of grades based on the urea-ammonium polyphosphate system. More recently Mitsui Toatsu has released information on the pilot plant development of the urea-ammonium polyphosphate system utilising oil prilling for the solidification step¹⁶.

Operating experience concerned with the production of UAP grades on a slurry process plant in India was noted at an FAI Seminar in 1972¹⁷. This plant is based on the TVA ammoniator granulator process for DAP.

Development work by Fisons Limited on the urea-superphosphate system, with particular reference to the use of chalk as a neutralisation agent for free acidity control was reported by Hemsley et al in

1972^{18,19}. These Papers also noted development and full scale experience in the manufacture of high analysis fertilizers based on urea and ammonium phosphate.

DEVELOPMENT OF FISON'S UAP GRANULATION PROCESS.

The USP system has considerable merit. It utilises two solid intermediates which can be manufactured cheaply and are in plentiful supply. The system offers a route to good quality medium analysis fertilizers easily adapted in nutrient rates to the needs of specific soils and crops. The system has particular advantage in areas of sulphur deficiency. These conditions apply in India, for example, where there is a large and long established superphosphate industry only partly utilised.

At the present time, the main effort of development and exploitation is undoubtedly being geared to the UAP system, since fertilizers based on this form of phosphate have a very high nutrient content and allow the maximum saving in costs of storage, bagging, distribution and application.

During 1967, Fisons commenced laboratory scale studies on the UAP system. These studies were based on the use of both prilled urea and concentrated urea solution, together with powder MAP (MINIFOS)²⁰⁻²⁴ as the P₂O₅ source.

The laboratory scale work indicated that the manufacture of UAP grades in the Fisons conventional granulation process was feasible, subject to some changes in the granulation stage. Laboratory assessment of the products suggested that there were not likely to be any unusual or unsatisfactory characteristics.

During 1968, continuous pilot plant work was carried out. Initially a small unit of up to 0.1 tph output was used. Later, a larger unit of up to 1 tph output was utilised. Both units were operated on a continuous 24 hour basis to ensure steady state conditions, and to provide material for market assessment.

In June 1970, a UAP granulation plant built according to the Fisons process was started up at the Huelva factory of Fertilizantes de Iberia, S.A. (FERTIBERIA). It is believed that this is the first granulation plant in the Western world specifically set-up for

the manufacture of high analysis UAP grades. Since then, FERTIBERIA has made an important contribution to the full scale development and commercial operation of the Fisons process.

The FERTIBERIA UAP granulation plant represents a major conversion of an earlier granular MAP and NPK plant built in 1965 according to a spray drum process. Although new equipment and considerable modification to the plant layout was necessary, the conversion was largely contained within the bounds of the existing building plan and floor elevations. The design output of the plant was 400 tpd (125,000 tpa) of the following grades:

18-18-18	20-10-10
15-15-15	13-13-20
12-24-12	

It was expected that the plant would operate with a utilisation of at least 7,500 hours per year.

The specified raw materials were crystalline or prilled urea, MINIFOS, potash and inert filler as required.

PROCESS ASPECTS.

The most important technical features stemming from the pilot plant work, and confirmed in commercial operation have been concerned with the granulation and drying stages.

1. Granulation in rotary drums or pug-mills takes place with a relatively low water content compared with other systems. Furthermore, the granulation is sensitive to quite small changes in the liquid phase content. For satisfactory granulation with the production of smooth spherical granules, the granulator temperature must be at least 75°C. This is achieved by the use of a hot fines recycle, and the exothermic heat of reaction from ammoniation of the MAP component. For some grades, the use of a small quantity of sulphuric acid (around 5 per cent of the formulation) is beneficial. A high granulation temperature further reduces the water requirement for granulation and ensures a low evaporative load in the drying system with negligible build-up on the drier surfaces. A typical granulation curve is given in Figure 1.

2. Although drying of UAP grades requires the use of low gas and material temperatures to avoid urea hydrolysis and material softening, the operation is not difficult. Water removal takes place at a higher rate than for other systems based on ammonium nitrate. The drying load not only reduced by the lower water content of the ex-granulator material, but also by the higher water content that can be tolerated in the products without the fear of poor storage properties. A typical drying curve is given in Figure 2.
3. Since the need for fines recycle is determined by the efficiency of the granulation device rather than the need to absorb excess liquid phase introduced by the feed materials, granulation proceeds at a much lower fines recycle ratio than that required for UAP systems such as that described by TVA where the feed materials are introduced to a large extent as aqueous solutions or slurries. Medium analysis grades containing 10 - 15 per cent urea and with a size distribution essentially in the range 2 - 4 mm can be granulated with a fines recycle ratio of around 1:1. A high analysis grade such as 18-18-18 containing over 30 per cent urea granulates with a fines recycle ratio of between 1.5 and 2:1.

DESCRIPTION OF THE FERTIBERIA UAP GRANULATION PLANT.

Prilled urea, potash, and inert filler as required, are recovered from bulk storage to the granulation plant intake system by a mechanical shovel. MINIFOS is fed directly to the weigh hopper from an adjacent MINIFOS plant. No crushing or screening is necessary for these materials.

The feed materials are weighed on individual Fisons designed continuous weigh belts, mixed on a collector conveyor together with return fines recycle material from a surge hopper, and then elevated to the granulation stage. Granulation takes place with the aid of steam in a pug-mill²⁵. Ammonia, and sulphuric acid as required, is also added at this point. The pug-mill discharge falls by gravity to a rotary conditioning drum, and from thence to the rotary drier. Hot air for the drier is provided by a naphtha burning air heater provided with a control system which allows the independent setting of the inlet and outlet gas temperatures. The ex-drier material is transported to a rotary cooler and from thence to the screening and crushing stage. Over-

size material is crushed and conveyed together with the undersize material and cyclone dust to the surge hopper at the head of the system. Product size material is passed to the coating and oiling drum, and from thence to bulk store.

The exhaust gas streams from the drier, cooler and dust suppression points are dry cycloned, and then scrubbed in a void spray scrubber.

COMMERCIAL OPERATION.

The FERTIBERIA granulation plant has now been in production operation for some thirty months. During this time the following grades have been manufactured:

8-36-16	10-20-20
9-18-27	12-24-12
9-18-27 + 2B	15-15-15
9-27-18	18-18-18

The grades containing lower levels of urea such as 9-18-27, 9-27-18, and 10-20-20 are manufactured at daily production rates of around 500 tpd. The 12-24-12 and 15-15-15 grades are produced at 450 - 500 tpd, whilst the 18-18-18 grade is produced at 410 - 430 tpd. The versatility of the plant has been demonstrated by the manufacture of 8-36-16, based solely on MINIFOS and potash, at a production rate well in excess of 500 tpd.

Following minor modifications to some of the mechanical handling system, and removal of superfluous process equipment, the plant has demonstrated its capability for a monthly production in excess of 12,000 tonnes, with a plant utilization of 90 per cent. It is expected that further increases in output and utilization will follow as a result of improved experience with the process.

Production runs are typically six to seven days in length, but occasionally are as short as two days. Grade changeover is accomplished smoothly with the minimum of lost time.

The routine quality control procedures are simple, and apart from occasional adjustment of the raw material flowrates to maintain the correct product plant nutrient analysis, the only other important need for care is concerned with regulation of the

drier in maintaining the appropriate product water content specification.

The physical appearance of the products is attractive. The granules have an adequate crushing strength, and are relatively spherical compared with grades based on ammonium sulphate or ammonium nitrate. The storage properties are good, it being possible to maintain bagged fertilizer in acceptable condition for at least nine months.

The granules have a uniform chemical analysis. The biuret content is negligible and is related to the content in the prilled urea feed. Although high analysis UAP products are hygroscopic and can readily absorb water in unfavourable conditions, satisfactory bulk and bag storage is entirely viable provided care is taken. It is good practice to bag the products in polythene bags shortly after manufacture, but where bulk storage is required, then a closed store building or air conditioning is helpful.

Some of the more important properties are listed in Appendix III.

SUMMARY OF THE PROCESS.

The new process provides a simple and attractive route to the manufacture of urea based fertilizers for those areas where urea is already an important source of fertilizer nitrogen for straight application.

The main feature of the process is the low capital investment for high capacity single stream plant which stems from the low fines recycle requirement. Capital investment is further reduced since the relatively low ammoniation level in the granulation device does not require the need for complex and expensive scrubbing facilities for the recovery of ammonia. An important feature of the process is its flexibility with respect to feed materials and product grades.

The product from this process can meet the most stringent requirements in terms of size range, storage quality, stability etc.

The process is well suited to the growing concept of manufacture of the basic intermediates, e.g. urea, ammonium phosphate, close to the source of the natural raw materials with the manufacture of complete balanced fertilizers at the agricultural areas. This

concept offers significant production and freight cost savings, since the intermediates can be manufactured in large economic plants serving a number of satellite consumer granulation plants perhaps many thousands of miles away²². The simplicity of the consumer granulation plant, custom designed to suit local agricultural requirements, is attractive to both developed and developing areas.

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DISCUSSION

MR. J.D.C. HEMSLEY (Fisons Limited, United Kingdom).

1. Urea is an attractive fertiliser in many countries and it is likely that within this decade it will become the most important source of nitrogen for fertiliser usage. Although urea is used principally as a straight nitrogenous fertiliser, there is a growing demand for complete high analysis fertilisers based on this form of nitrogen.
2. High analysis fertilisers incorporating urea are at present being manufactured in Spain, Japan, India and the United Kingdom. There are several projects in the planning stage for urea based products in the South Americas, the Eastern European countries, Asia and the Far East.
3. Fisons commenced a research programme for the production of urea-ammonium phosphate fertilisers in 1967. Pilot plant operation confirmed the suitability of a modified conventional granulation process. The first plant to be erected according to this new process was put into operation by Fertiberia during 1970.
4. The research programme was extensive and included such aspects as:
 - The effect of temperature, water content, and fines recycle on the granulator system.
 - The evaluation of drying rates, including the effect of temperature on urea hydrolysis reactions, and the softening characteristics of the material.
 - The evaluation of product quality in terms of storability, hardness, hygroscopicity and other related properties.
5. The pilot plant programme confirmed the viability of the process under continuous operation and provided material in tonnage quantities for market assessment and full scale storage tests.

6. The process route selected by Fisons was based on the use of solid raw materials and intermediates: That is to say prilled urea, monoammonium phosphate powder, and crystalline potash. This route was preferred to that utilizing urea solutions and ammonium phosphate slurries because of the much lower fines recycle requirement, and the need for maximum flexibility combined with equipment simplicity.
7. It was also expected that the "solids" route would be of considerable attraction in the developing countries where simple NPK granulation plants located in the agricultural areas and supplied by centralized major urea and ammonium phosphate factory complexes, makes good logistic sense.
8. Finally, the conventional granulation process was chosen for development because of its already well-proven flexibility with respect to raw materials and products - an aspect of especial interest to the marketing executive - and the attractive capital investment, with its emphasis on a low foreign currency requirement.
9. We often hear of interest in new processes which eliminate the conventional rotary drier or processes which employ a prilling stage with a very low recycle of off-grade material.
10. A rotary drier is a simple piece of equipment made of ordinary steel with an operating life of fifteen years or more, whilst the prilling tower has serious restrictions on flexibility.
11. Naturally, we are all attracted by concepts employing novel principles, but what is really of importance is the economic cost of fertilisers, and the capability of process plant to operate twenty four hours a day seven days a week with a flexible production programme.
12. The Fisons UAP process has a number of attractive features: the fines recycle ratio is less than 2:1 and this is determined more by the inherent efficiency of the granulation device than by the need to absorb excess liquid phase.
13. Drying is easier than expected. Emphasis on the maintenance of a relatively high granulation temperature ensures negligible build-up in the drier over long periods of time.

14. Limited granulator ammoniation coupled with the rapid absorption capability of powder ammonium phosphate obviates the need for complex ammonia scrubbing equipment.
15. These features ensure, first, a low capital investment for large capacity single stream units with a high utilization factor; secondly, a flexible plant with the ability to change grade with the minimum of lost production time, and thirdly, simple operating procedures with relatively unskilled process labour.
16. Finally, a recent development at Fisons' Levington Research Establishment is the granulation of straight urea melts for the production of a large urea granule. Some work still remains to be done, but it is already clear that this capability should offer considerable attraction for bulk and bag blending operations.
17. I now have pleasure in introducing my co-author, Sr. Francisco Roig to present some aspects of the commercial operation of the UAP granulation plant at Huelva.

MR. F. ROIG (Fertiberia, S.A., Spain)

In the text of the documents which were sent to you in which the Fisons-Fertiberia Process for the manufacture of granulated compound fertilisers utilising urea as the principal source of nitrogen was described, and following what Mr. Hemsley has said to you, I think that it might be of interest if I explained in as much detail as possible how the major problems of the manufacture of compound fertilisers involving urea have been resolved industrially.

We know from everyone who has worked with this type of compound that one of the biggest problems encountered is that the addition of urea has the effect of lowering the fusion point of the mixtures. At the same time it is necessary to obtain the highest possible degree of dryness, in order that the finished product should have high storage qualities. At present the result of this is a limitation of production capacity so as to obtain good properties of storage. Solving this problem was not easy, and proved in practice to be the greatest difficulty we had to overcome in our present plant. We would remind you that Fertiberia first used urea in the manufacture of granulated compounds at the beginning of 1968 in a small plant with a capacity of 10 t.p.h. rented from another company. The grades manufactured were 8-24-15, 12-12-24 and 12-24-12, containing, in addition to monoammonium phosphate, a small proportion of superphosphate.

The plant consisted of a granulating pan and it was necessary to evolve a process of granulation by adding sulphuric acid, ammonia - partly in liquid form and partly in gaseous form - and water. The heat generated by the reaction was used for drying the product which was evidently of good quality; so much so that we understand the current operators of the plant still to be producing this type of compound by using the process developed at that time.

The experience acquired in this plant, together with test-runs on a pilot plant first led us to believe that the percentage of granulated product obtained through the use of a screw granulator with a granulating drum would be low, and that it would be necessary to rely on a partial fusion of the product inside the dryer. The plant was started up with this concept in mind, but it soon had to be relinquished for, although the degree of residual humidity was low, the granulation rate was insufficient and, also, the viscosity of the melted product made it stick to the walls of the drum and dryer where it formed a layer of partially crystallised product, gradually reducing the volume of the drum. This meant that work had to stop for cleaning and production time was lost as a result.

All efforts were then concentrated on ensuring that the whole of the granulation process should take place inside the drum so that, in order to dry the product, it was necessary to work at a temperature low enough to avoid reaching melting point in the dryer.

Since the drying air had to be at a low temperature, it was necessary that the water content of the wet product be kept as low as possible, and we had to devise a granulation process that involved as little water as possible.

This was done by increasing the temperature of the product inside the granulating drum and by carefully combined regulation of the various factors affecting the granulation process - the quantity of steam, the recycling rate and the pH of the mixture - in such a way that the amount of steam should be just that required to moisten the product and no more.

Under these conditions, the product that enters the dryer has already been granulated and has a relatively low degree of humidity; when it comes out its degree of humidity is lower than 1% which means that the product presents good storage characteristics and does not need to be bagged immediately. The bagged product has sometimes been

stored for 9 months and more without deteriorating.

The low water content of the product to be dried has the advantage of having a low specific fuel consumption (15 to 20 kg/tm).

The melting temperature of the mixture is generally lower, the greater the proportion of urea it contains and in this way we have found that the formula for which it has been most difficult to define parameters has been that of 18:18:18 which melts at drying air temperatures of 120°C only. Today this formula presents no particular problem.

We shall be very pleased to welcome you next Thursday to our operation in Huelva, and to show you in detail the plant at work.

MR. L. NILSSON (Supra, Sweden):

1. On page 5 you mention that new equipment and considerable modifications to the plant layout were necessary. Could you tell us what new equipment has been installed and what modifications have been made? It would also be interesting to know what changes generally have to be made, if one wants to produce urea-based products in a plant constructed for AN-based products.
2. On page 5 you tell us that the granulator temperature must be at least 75°C. In figure 1, you show granulation curves for temperatures below 75°C. Could you give us an explanation?
3. You mention on page 6 that water removal takes place at a higher rate for UAP than for AN-based systems. This must be wrong according to figure 2, where the rate is higher for AN-based fertilisers. Temperature, structure and critical relative humidity of the granules must have a big influence on the drying rate. Could you comment on this?
4. Why do you cool the total recycle? Is it necessary for urea-based products because of problems with crushing? It would be better from an economic point of view to have hot screening and only cool the commercial product. I think you yourself put the same question to Mr. R. D. Young in the Sandefjord meeting.
5. On page 7 you mention different production rates for different products. Could you tell us about the limiting factor or factors? Is it granulation, drying or something else?

MR. F. ROIG:

1. When we were doing the research work for this paper, the Fertiberia plant was manufacturing mono-ammonium phosphate. It has been converted and for economic reasons we have tried to make the most of the equipment in place. So we kept and we still use screens, crushers, and granulating drums which have been converted into coolers and we also kept the combustion chambers. New equipment that we have installed includes a plate screw which is used as a mixer, granulating drums and drying drums.

MR. J. HEMSLEY: Mr. Nilsson asked:

1. What changes had to be made to a plant to enable it to produce urea based compounds. This is a difficult question because it all depends on the plant that Mr. Nilsson wants to convert. There are also commercial implications. I will be delighted to discuss this afterwards.

2. His second question is on the granulator temperature in figure 1. It is true that the curve stops at about 73°C and indeed during our pilot plant and batch granulation experiments, this was the limit of the work carried out. Part of the experience which has been gained by Fertiberia involves granulation at a slightly higher temperature and, if I say 75 to 80°C, it is not too much of an extrapolation of the curve.

3. You are quite right to say that the drying rate for ammonium nitrate based fertilisers is higher not lower than that for urea based fertilisers. This is the rather loose English way in which we sometimes oversimplify matters. What I really meant to say was that it is easier to dry urea based fertilisers than ammonium nitrate based fertilisers. The required retention time for example, is significantly shorter. The water content of material going into the dryer is lower, and the degree of drying for good storage properties is less. The author of the previous paper referred to the difficulty of drying urea based grades in conventional plants. This is a comment frequently made and is, I suspect, based on experience with old plants not specifically designed for urea. It is our experience that a conventional granulation plant designed from the start for the use of urea does dry satisfactorily in an economically sized installation.

Ten years ago we thought an NPK fertiliser containing 5% of urea was difficult to make; five years ago we thought 10% of urea in an NPK fertiliser was difficult to make. Now we talk in terms of 30, 40 or even 50% as the limiting quantity of urea.

4. Why do we cool the total recycle particularly in the light of the question that I put to Mr. Hignett in the Sandefjord meeting. I confess that I cannot recollect the question but the Fertiberia plant was the first plant we designed to use urea in the manufacture of high analysis fertilisers. I think we built it in the English tradition with both belt and braces to keep our trousers up. We put in a recycle cooler and we put in a product cooler. The fact remains that neither are used.

MR. ROIG: In the specific case of the manufacture of 18:18:18, the element which governs the production capacity of the plant is the total recycling circuit which is well balanced at the centre. The daily output of this grade is well above that planned. Other formulae are manufactured with a lower recycle rate and a markedly higher output.

MR. K. SHARPLES (Seabright Chemicals, United Kingdom): I would like to refer to the question put by Mr. Nilsson about what changes have to be made to a conventional plant, if you want to make urea based compounds. In the first place you have to know how to dry this material, and this is relatively simple provided that the plant has a very good air heater with a good turn down ratio so that the product temperature does not swing by more than 0.5°C. You must have a pre-cooled circuit so that all the material leaving the dryer goes straight to the cooler. This ensures that the material is screened and crushed at as low a temperature as possible. The fines recycle should not be too low as recycle does help to smooth out the process problems. I agree with a lot of what has been said by Mr. Hemsley. I think he is pushing his point a little bit on the water content of the product. If I understand him correctly, he says 0.8-1% is satisfactory. My experience from about 14 plants is that 0.3% is nearer the mark; but this is not difficult.

MR. HEMSLEY: I am not sure whether or not Mr. Sharples wants me to invent a reply. Perhaps Mr. Nilsson should make some comment?

MR. FROCHEN (Compagnie Française de l'Azote, France): I should like to know whether, in a plant handling urea, it is possible to switch from urea-based manufacture to ammonium-nitrate based manufacture without too many problems, and whether one should take any special precautions.

MR. HEMSLEY: Mr. Frochen was asking what special precautions should be taken in a plant which makes both urea based fertilisers and ammonium nitrate based fertilisers. This is a very interesting question, and one to which my Company has given some attention during the past few months. I think the answer is that it is very difficult to switch from ammonium nitrate based to urea based or vice-versa. There are decomposition hazards to think about. Mixtures of urea and ammonium nitrate are not very good. There are hygroscopicity matters to think about as well. Altogether, urea and ammonium nitrate together in the solid phase is a rather nasty mixture.

MR. M. MORAILLON (Générale des Engrais, France): I should like to ask a question relating to Appendix 3. I see that there is resistance to crushing of the order of 0.7 kg/granule, 0.9 kg/granule. I would like to ask whether these figures are correct and, if so, whether one can be satisfied with such a low level of resistance to crushing?

MR. HEMSLEY: The hardness of urea based fertiliser is lower than that of ammonium nitrate based fertiliser. We think that 0.5 is a satisfactory minimum in terms of kg/granule. Much depends of course on how you measure this and what size granule is used from the test sample. I would like Mr. Roig to make some comments on this. Has he noticed any problem here?

MR. ROIG: Up to now, we have encountered no difficulty with the resistance of the granules. The product is hard and it can be stored in bags on pallets to a height of 4 pallets. We have noted that long after it had been removed from the pallets the product was not crushed in any way. I am not sure whether that is exactly what you wanted to know.

MR. MORAILLON: No, the question was about spreading. I wanted to know if, with centrifugal spreading, the resistance of the granules was sufficient to obviate excessive dust.

MR. ROIG: I must confess that I know nothing about this aspect of the matter.

MR. C.H.M. VINKE (Windmill, Holland):
The preprint states that a pugmill is an essential piece of equipment, that ammoniation is important and that you use quite a considerable amount of MINIFOS MAP in this plant so that you have to take into account the pH of the product. I would therefore like to ask the authors if they consider the pugmill to be the most suitable equipment for ammoniation? One might expect leakages of ammonia from the pugmill. The second question I would like to ask is: when you speak about size distribution you say that it is essentially in the range of 2 to 4 mm. Now what is meant by essentially? Is this 50% or is it for the whole of the product? The last question is on the compound 8 - 36 - 16 which you also succeeded in making in the plant up to an amount of 500 tons/day. Has this also essentially the same size distribution?

MR. HEMSLEY: The answer to your first question is no! This is another example in this plant of 'belts and braces'. We put in a pugmill and we also put in a rotary drum; the two pieces of equipment being in series. The original concept, 4 years ago, when this plant was built, was that granulation would take place in the pugmill, and that the second unit, the drum, would be used for rounding off the product. In fact, in many discussions with my colleagues in Fertiberia, we have concluded that in any new plant we would use a rotary drum and we would carry out the ammoniation in it. There is no doubt that in the pugmill some ammonia is lost and we would expect that in the rotary drum the loss would be very very much less.

I would like to refer the question of the size range of the product to Mr. Roig.

MR. ROIG: In Spain we now have additional restrictions on the amount by which the product may exceed the specified content. I do not have the exact figures, but in view of the exigencies of the market in Spain, we always endeavour first to comply with the law and then, secondly, to satisfy the buyer. In principle, about 1% of the finished product falls outside the 2-4 mm range.

APPENDIX 1

CAPACITY, PRODUCTION AND CONSUMPTION

DATA FOR UREA

	CAPACITY*		FERTILIZER PRODUCTION	FERTILIZER CONSUMPTION
	1961-62	1969-70	1969-70	1969-70
West Europe	508	2,329	1,084	303
East Europe	65	2,621	1,678	1,292
North America	446	1,852	1,117	765
Central America	18	166	133	125
South America	-	70	45	138
Africa	46	185	87	169
Asia	542	3,233	2,340	2,853
Oceania	-	111	38	77
WORLD	1,625	10,567	6,521 [†]	5,722

'000 tonnes Nitrogen per annum

* Includes capacity for feed and technical grades

† Total world production 7,515 including 180 for feed grade and 813 for technical uses.

Data provided by British Sulphur Corporation (ref.1).

APPENDIX II

MAJOR CONSUMERS OF FERTILIZER UREA

China	910,000 tpa	Bulgaria	130,000 tpa
India	795,000 tpa	Italy	100,100 tpa
USA	750,700 tpa	Czechoslovakia	82,000 tpa
USSR	650,000 tpa	Australia	75,000 tpa
South Korea	250,000 tpa	Mexico	72,700 tpa
Pakistan	230,000 tpa	Taiwan	72,000 tpa
Poland	210,000 tpa	UAR	62,000 tpa
Japan	195,000 tpa	Spain	60,400 tpa
Indonesia	185,000 tpa	UK	60,400 tpa
Rumania	135,000 tpa	South Vietnam	45,000 tpa

Data in tonnes nitrogen for year 1969-70.

Data provided by British Sulphur Corporation (Ref.1)

APPENDIX III

PROPERTIES OF UAP PRODUCTS

	18-18-18	15-15-15	12-24-12	10-20-20
P ₂ O ₅ water solubility - %*	96	96	96	96
pH number †	4.9 - 5.2	4.9 - 5.2	6.7	6.7
Water content - %	0.8	1.0	1.2	1.2
Biuret content - %	0.4	0.2	0.2	0.2
Bulk density - kg/m ³	950	1,000	1,020	1,040
Crushing strength - kg/granule	0.7	0.9	-	0.5
Caking strength - kg/cm ² ‡	0.3	0.3	0.3	0.3
Size range - mm	2 - 4	2 - 4	2 - 4	2 - 4

* Morocco based MINIFOS intermediate

† 10 per cent solution

‡ Fisons standard accelerated test²⁶

APPENDIX IV

TYPICAL UTILITY DATA

The following data are representative of the grades presently made by FERTIBERIA. It should be noted that the steam consumption to the granulation device is particularly high due to losses from the pug-mill which would not be expected in a rotary drum granulator.

Utility	Condition	Usage/tonne
Steam	Low pressure	100 - 150 kg
Fresh water	-	Nil
Cooling water*	3 kg/cm ²	0.5 m ³
Naphtha fuel	7 kg/cm ²	15 - 20 kg
Electricity	380 V. 3 phase	20 kWh

* Cooling or similar quality for scrubbing purposes

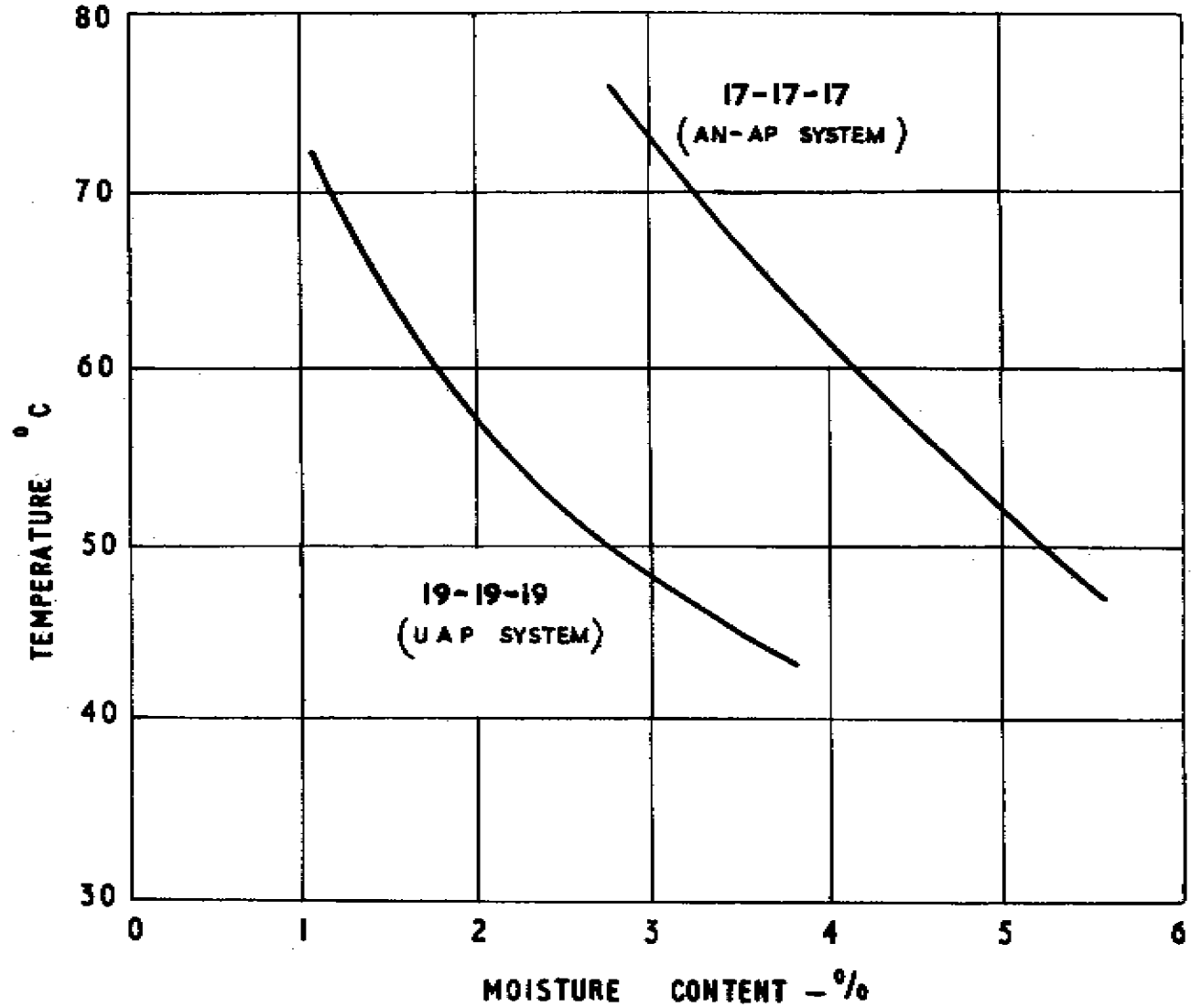


FIGURE I — GRANULATION CURVES FOR 1-1-1 FERTILIZER

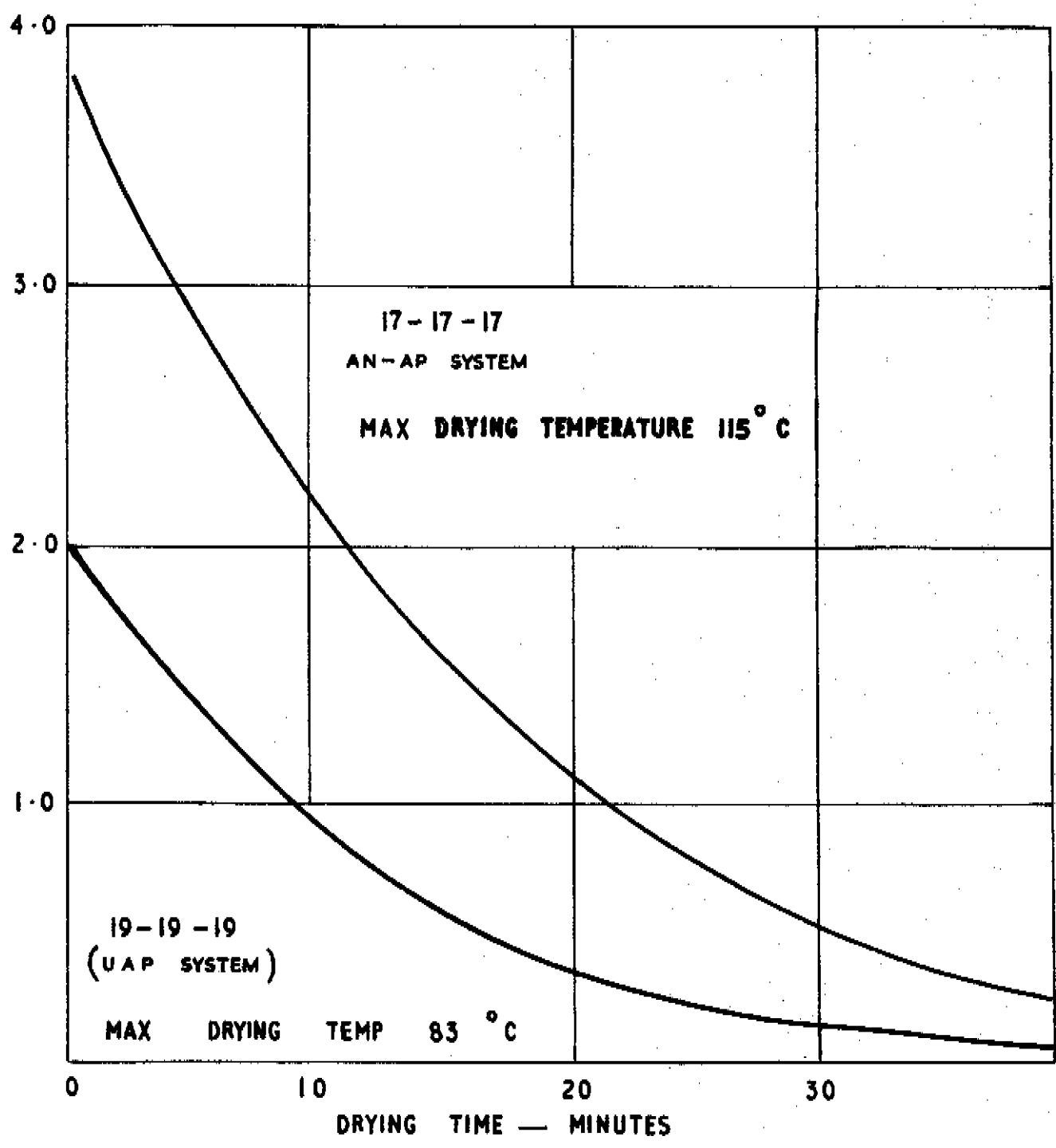


FIGURE 2 - DRYING CURVES FOR 1-1-1 FERTILIZER