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Kiev, USSR, 21 September - 1 October 1971
New Delhi, India, 2 - 13 October 1971

Agenda item IV/9

MONOAMMONIUM PHOSPHATE AS AN INTERMEDIATE
FOR COMPOUND FERTILIZER PRODUCTION

by

I. Podilchuk
W.F. Sheldrick
Fisons Limited
Felixstowe UK

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SUMMARY

MONOAMMONIUM PHOSPHATE AS AN INTERMEDIATE FOR
COMPOUND FERTILIZER PRODUCTION^{1/}

by

I. Podilchuk
W.F. Sheldrick

Fisons Limited
Felixstowe UK

The rapid growth of high analysis granular NPK fertilizers in the U.K. during the last decade has caused a considerable interest in the manufacture of a powder ammonium phosphate intermediate capable of being used in both new and existing conventional granulation plants for the production of such grades as 20-10-10, 17-17-17, 12-24-12 and 13-13-20.

Fisons Limited has developed a novel process for the production of such a material which is based on the ammoniation of wet process phosphoric acid under conditions of elevated pressure and temperature such that a concentrated MAP solution containing around ten per cent water is produced. This solution is then flash dried in a short natural draught tower to produce a fine prill-like powder containing around six per cent water. The powder product - MINIFOS - is non-hygroscopic with a bulk density of around 800 kg/m^3 . It can be handled and transported with conventional equipment used in the fertilizer industry.

MINIFOS is a highly water soluble material containing around 65 plant food units. It is completely compatible with the other important fertilizer intermediates such as ammonium nitrate, urea, and superphosphates. Since the material contains a relatively

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small amount of water, its incorporation with other materials in conventional rotary drum granulation plants takes place with a fines recycle ratio which is determined more by the efficiency of the granulation device than the need for liquid phase absorption. Recycle ratios in the range 1:1 to 2:1 are typical with the use of powder MAP. The replacement of part or all of the P_2O_5 component by MINIFOS in slurry processes where the neutralization of phosphoric acid is carried out "in situ", and recycle ratios of the order of 3:1 to 8:1 are typical, results in a considerable increase in output with only minor modifications to the plant.

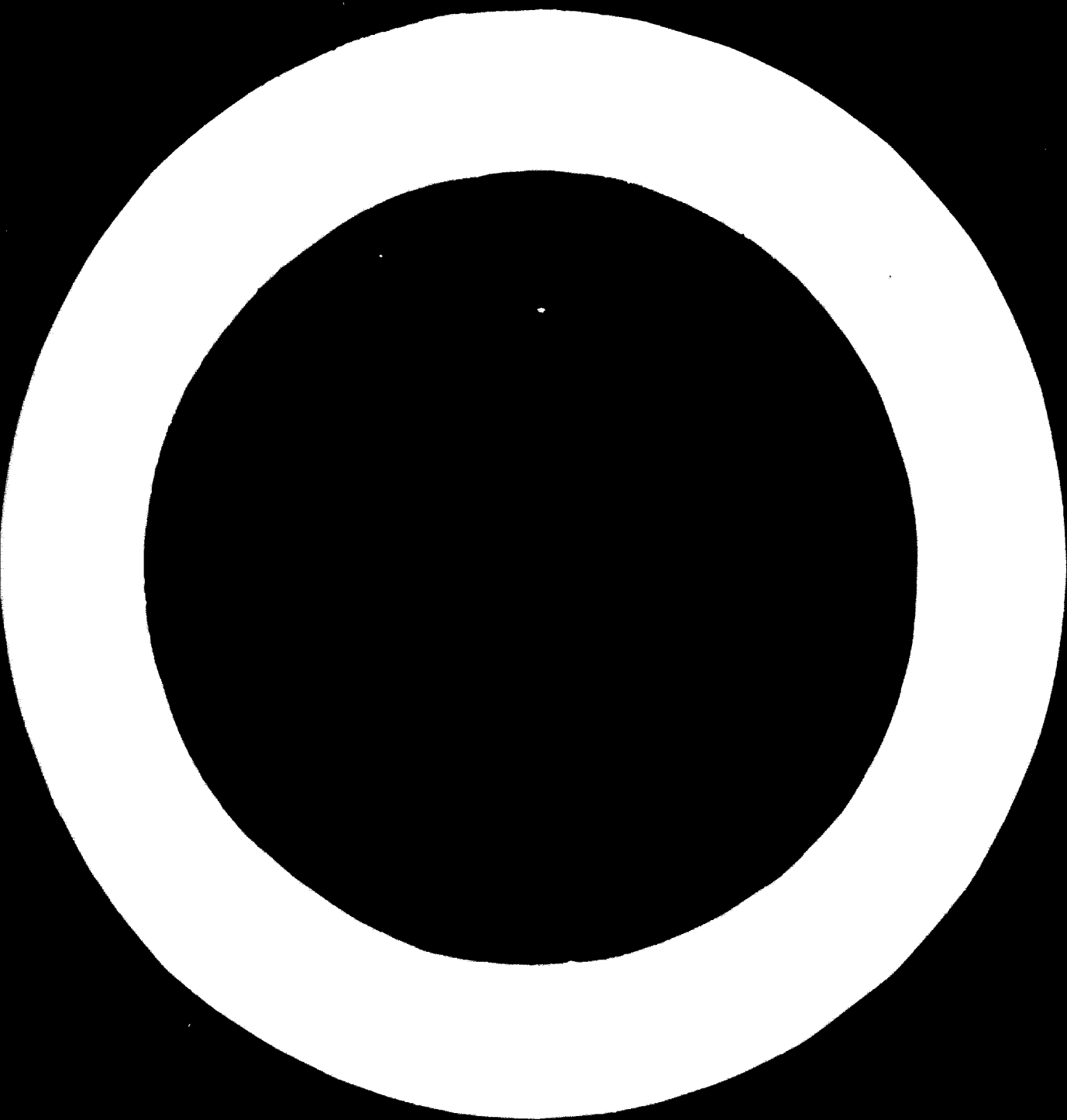
MINIFOS has special attraction as a high grade intermediate manufactured close to the phosphate rock source which is then shipped to the consumer granulation plant located in the important agricultural areas. The saving in freight cost and terminal facilities compared with phosphate rock or even phosphoric acid is significant, whilst the simplicity of the consumer granulation unit is of note. Since the pH of the material is in the range 3.5-4.0, the expensive and complex scrubbing facilities necessary for ammonia recovery where intermediates such as DAP are used can be avoided.

The new Fisons process represents an important technological advance in the manufacture of phosphatic intermediates, providing an important and proved route to the manufacture of high analysis complete fertilizers with the minimum capital investment and operating cost.

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

CONTENTS

	Paragraphs	Pages
I Introduction	1-9	5-7
II The Process	10-18	7-9
III Minifos Plant	19-26	9-11
IV Utility and Capital Requirements	27	12
V Properties of Minifos	28-31	13-14
VI Monoammonium Phosphate as an Intermediate Compound Fertilizer Production	32-39	15-25
VII Figures		26-32
VIII References		33-34



I. INTRODUCTION

1. During the last decade there has been a spectacular expansion in the production of ammonium phosphate for use both as a "straight" fertilizer and as an important intermediate in the manufacture of complete NPK fertilizers. In 1960, the United States produced only 10 per cent of its total P_2O_5 capacity as ammonium phosphate, but by 1965, at the height of the fertilizer boom, the manufacturing capacity had been boosted to around one million tonnes, representing over 25 per cent of the total P_2O_5 output.

2. The chief advantages of ammonium phosphate are based on its high overall plant food content in which a significant level of low cost ammonia is chemically combined to yield an almost completely water soluble product without loss of "available" P_2O_5 . Its agronomic properties for most soils and crops are highly acceptable, whilst its compatibility - particularly in the mono form - with other fertilizer materials and intermediates is particularly noteworthy. In the United States, the main product has been granular DAP (18-46-0), a substantial proportion of which is used as a base component in the production of bulk blended fertilizers. Western Europe has seen a similar growth rate in the production of ammonium phosphate. In this area, where process technology for the manufacture of very high analysis fertilizers developed more rapidly than elsewhere, ammonium phosphate has played a key rôle.

3. The production of granular DAP is now largely based on the route developed by TVA during 1960; a route which is now applied in nearly all new granular ammonium phosphate installations (1). This process and its variants is offered by engineering contractors within both the United States and Europe. Briefly, 40 per cent P_2O_5 wet process phosphoric acid is neutralised with ammonia in a tank reactor to a mole ratio $NH_3 : H_3PO_4$ of around 1.35 : 1. The reaction is carried out under boiling conditions at a temperature of $115^\circ C$. Steam driven off by the exothermic heat of reaction is scrubbed with part or all of the phosphoric acid feed to recover the small amount of ammonia contained therein. The ammonium phosphate slurry from the reactor containing some

18 - 22 per cent water is pumped to a rotary drum granulator where further ammoniation is carried out to raise the $\text{NH}_3 : \text{H}_3\text{PO}_4$ mole ratio to around 1.9 : 1.

4. Recently Fisons Limited in the United Kingdom has introduced the concept of carrying out the first ammoniation step of the TVA process under conditions of slight pressure and a higher boiling temperature in order to take advantage of the steep solubility curve (figure 1) of ammonium phosphate in water. This allows the production of a slurry with around 12-15 per cent water which in turn leads to a lower water evaporation duty and a reduction in the solids loop recycle ratio requirement from around 5-6 : 1 to less than 4 : 1 (2).

5. In the agriculturally developed countries of Europe, only relatively small quantities of ammonium phosphate are used as a "straight" fertilizer, and there is no base phosphatic fertilizer industry comparable to that existing in Florida. The ammonium phosphate component in high analysis fertilizers is manufactured principally 'in situ' from the ammoniation of wet process phosphoric acid at the head of the NPK fertilizer granulation facility.

6. Another route of growing importance, pioneered in the United Kingdom, is the use of ammonium phosphate powder intermediates - principally monoammonium phosphate - in the manufacture of complete balanced fertilizers. This route has some important advantages: capital investment for high output granulation units is less since the parasitic recycle requirement for liquid phase absorption in the granulator is lower, whilst the introduction of part or all of the P_2O_5 component as a solid intermediate in existing neutralisation-type granulation plants leads to a very significant boost in capacity with only minor equipment modifications. The production of a powder intermediate is relatively simple and cheap since there is no requirement for the production of uniformly sized granules of low water content.

7. There are two important processes for the production of powder ammonium phosphate - both developed in the United Kingdom - initially designed to serve the particular requirements of its fertilizer industry, but now having a much

broader appeal, and especially as a convenient route for P_2O_5 transport from the phosphate rock producing countries.

8. The SAI process, developed in the early part of the last decade is based on the production of an ammonium phosphate slurry similar to the first stage of the granular TVA process which is then "back-titrated" with phosphoric acid to the MAP stage in a "moisture disengagement vessel" when the slurry solidifies. This device is followed by a screening and crushing unit after which the powder product (phoSAI) is discharged to bulk store. Plants operating according to this process exist in the U.K., Canada and Japan (3).

9. The Fisons powder MAP process (4, 5, 6) developed during the period 1964-65 is described in the next section. The process takes advantage of boiling point elevation at moderate pressure. The product, MINIFOS, is a fine powder MAP eminently suitable as a solid intermediate raw material for granulation purposes.

II. MINIFOS PROCESS

10. The new process developed by FISON'S has two main steps. The first step is the reaction between concentrated wet process phosphoric acid and anhydrous ammonia under conditions which allow the formation of an exceptionally concentrated yet fluid mono-ammonium phosphate solution. The second stage is concerned with the flash drying and cooling of the concentrated MAP solution to a fine prill-like powder.

11. The reaction system is designed to take advantage of the considerable boiling point elevation resulting from operation at moderate pressure. In practice the operating conditions are about 3.1 kg/cm abs., 170°C and 10 per cent water content (figure 2). The ammonium phosphate solution produced in this pressure reaction system is completely fluid, and it can thus be handled safely in pipework and simple flow systems without fear of blockage or build-up.

12. The required phosphoric acid concentration is dependent on a number of factors, but chiefly, the acid temperature and whether it is "black" or clarified acid, and the physical state of the anhydrous ammonia feed. For example, gaseous ammonia at 30°C with "black" phosphoric acid at ambient temperature would necessitate a concentration of 47-49% P₂O₅ whereas acid at 90°C would need a concentration of around 44% P₂O₅. On the other hand the use of liquid ammonia would require a feed phosphoric acid concentration of around 50% at 40°C.

13. In practice, it is usual to employ a slightly stronger phosphoric acid than the minimum in order to allow for the normally expected variations in concentration, temperature and solids content. A small quantity of water is thus added to the reactor to allow for these variations and thus maintain the reactor operating temperature constant. It has been found that the operating temperature has an important relationship with the water content of the reactor solution and the final product. A change of 2°C affects the product water content by about one unit of per cent (figure 3).

14. The considerable heat of reaction between phosphoric acid and ammonia is sufficient to drive off a large quantity of water as superheated steam. At an NH₃:H₃PO₄ mole ratio of 1:1, approximately 1.4 kg of water are removed per kg of ammonia feed in the reaction step. Since the vaporization of one kg of ammonia requires little more than 0.6 kg of steam, there is more than sufficient waste steam available for this purpose and a notable steam economy in the preceding phosphoric acid concentration stage is entirely viable.

15. Under the reaction conditions, the partial pressure of ammonia above the concentrated mono-ammonium phosphate solutions where the mole ratio NH₃:H₃PO₄ does not exceed 1:1 is negligible even at a temperature of 170°C. Since the reaction system is operated at pH 3.5-4.0 the process can be operated at a high nitrogen efficiency without the need for scrubbing, provided sufficient mixing is designed into reactor.

16. The use of the stirred-vessel reactor rather than a jet or pipe reactor ensures a controlled steam release from the process and enables fluctuations in the feed flow to be absorbed without harmful variations in product quality, or ammonia loss from the reactor. It also allows impurities entering with the phosphoric acid, or precipitated during the reaction, to be suspended in the solution rather than building up as a scale on the reactor surface, as is likely with a pipe reactor.

17. In the second step, the concentrated MAP solution is ejected from a nozzle into a simple spray tower with a natural draught of air entering at ambient temperature. Under these conditions, further water is flashed off and in doing so the MAP solution is rapidly cooled and solidified into small particles. The product, as it falls down, becomes further cooled by the updraught of air and it is recovered at the bottom of the tower as a powdery material containing 5 - 7 per cent water depending on the reactor conditions and spraying control setting. The overall quantity of water driven off in the process is around 1.7 kg per kg of ammonia feed.

18. Because the water lost in the flash drying step represents only about 20 per cent of the total released in the process it is not sufficient to saturate the air flowing through the tower, and no plume is visible from the tower exhaust.

III. MINIFOS PLANT

19. A simplified flowsheet is shown in figure 4. Wet process phosphoric acid is pumped to a stirred tank reactor capable of operating at up to 3 kg/cm² gauge. The reactor is fitted with a turbine impeller and wall baffles to promote a high degree of agitation. The material of construction is generally 316 ELC or its equivalent unless a significant chloride content is present. In this case the material may be of the type typified by Incoloy 825.

20. Ammonia gas from a vertical shell and tube vaporizer is piped to the base of the reactor where it is injected into the eye of the reactor impellor. The vaporizer is supplied with waste superheated steam from the reactor except at start-up when boiler steam is required for a short period. Surplus steam from the reactor is let down through a back-pressure control valve and it is then vented to atmosphere, condensed, or passed to another process unit. Part of the vaporizer condensate is returned by means of a pump to the reactor; the flow being regulated to maintain the reactor temperature, and thus the product water content, constant at the desired level.
21. Where stronger acid of around 50 per cent P_2O_5 is available, there is no need to vaporize the liquid ammonia and this represents a relatively considerable saving in equipment, including reactor size, and instrumentation. As with gaseous ammonia, the liquid is injected into the eye of the impellor. Water for reaction temperature control has to be supplied in this case from outside the plant battery limit.
22. The pilot plant data has shown that very high steam release rates from the reactor could be achieved without entrainment. The highest rate noted was 1160 kg/hour.m^2 . Full scale plants have been operated at steam release rates of 790 kg/hour.m^2 without entrainment and even higher loadings can be expected under favourable conditions. There seems little doubt that pressure ammoniation enables the use of smaller cross-sectional area reactors for MAP production than is possible with atmospheric ammoniation.
23. The concentrated MAP solution flows from the bottom of the reactor and through steam jacketted pipework to a special nozzle at the top of the natural draught tower. This nozzle combines the duty of flow control, spray formation and control of the particle size. The nozzle has a pneumatically actuated valve plug which is positioned by automatic control to maintain the solution in the reactor at a constant and optimum level. The level control primary element used for this purpose is of the type based on the buoyancy of a submerged float. Considerable changes which can occur in the density of the reactor contents, due to changes in the operating conditions, affect the output

from this type of level element, and a supplementary device based on electrical conductivity is employed to determine the absolute level so that the main control system can be reset as necessary.

24. The tower itself is a very simple structure which can often be installed within an existing process unit building. The tower walls are fabricated from synthetic fibre material tied back to a supporting structure. The top of the tower is vented to atmosphere through a stack. The bottom of the tower is fitted with air entry louvres and a simple rotary scraper for product recovery.

25. The process is adequately instrumented to ensure push button starting and stopping, whilst the process conditions are fully automated to ensure stable operation with the minimum of attention. Alarms and automated shut down with steam self purging system are also included. Phosphoric acid is metered by means of an electromagnetic flowmeter; ammonia by orifice plate. The make-up flow is automatically regulated to maintain the reactor temperature constant, and the vapour space pressure is also maintained constant by automatic means. A simple pH determination by means of test papers is the only local analytical control required.

26. Full scale units have been operated continuously for over four weeks, with a typical utilisation of over 8,000 hours per annum. The maintenance cost is less than 5% per annum. Reactor life is likely to be in several years provided the chloride level in the acid is within the limits for the material for construction chosen. The tower wall fabric, which is relatively cheap has an expected life of over two years.

IV. UTILITY AND CAPITAL REQUIREMENTS

27. The new process represents an important technological and economic step forward in the manufacture of MAP intermediate. This is best illustrated by comparing the utilities and manufacturing costs with a conventional granular MAP process making 'pin-head' size material for use as a fertilizer intermediate. The data is based on an output of 20 tonnes per hour.

Table I

Requirements	NINIFOS (Powder MAP) (0.1 - 1.5 mm)	Small Granular MAP (1 - 3 mm)
	20 tph	20 tph
Utilities		
Steam kg/tonne	50	2.5
Water litres/ tonne	Nil	45
Power kvh/tonne	2.25	24
Fuel kcal/tonne	Nil	100,000
Labour men per shift	0.5	4
Capital Investment - battery limit	£140,000	£700,000

V. PROPERTIES OF MINIFOS

28. MINIFOS is stored in bulk and can be handled by all the conventional mobile and fixed handling equipment used in the fertilizer industry. Immediately after manufacture the material takes on a slight initial "heat-set" but there is no difficulty in recovery from bulk store and its storage properties can be generally regarded as equivalent to cured superphosphate and other raw materials. The absence of fine dust during handling operations is particularly noteworthy. This is because the quantity of dust size particles is very small.

29. The product is non-hygroscopic, and under normal storage conditions will tend to loose moisture. The most important properties of MINIFOS are listed below:

Analysis	:	see Table II
Water Content	:	5 - 7 per cent
pH Number	:	3.5-4.0 (10 per cent solution)
Bulk Density	:	360 kg/m ³ - loose
	:	950 kg/m ³ - tamped
Angle of Repose	:	38 degrees
Size distribution	:	87-96 per cent below 2.0 mm
		80-92 per cent below 1.5 mm
		60-80 per cent below 1.0 mm
		26-51 per cent below 0.5 mm
		2-6 per cent below 0.15 mm

As mentioned in Section II the size of the material can be controlled to some extent by regulation of the spray nozzle.

30. The chemical analysis of the MINIFOS is dependent on the rock source and impurities in the acid feed as indicated in Table II below:

Table II Typical MINIFOS Analysis Achieved (% - On Dry Basis)

Rock Source	N	Water soluble P ₂ O ₅	Citrate P ₂ O ₅	Total P ₂ O ₅	Water solubility P ₂ O ₅	Citrate solubility P ₂ O ₅
Morocco - black acid	11.2	53.6	55.1	55.5	96.5	99.3
- settled	11.5	54.7		56.5	96.8	
- clarified	12.2	55.7	57.1	57.5	97.1	99.3
Florida uncalcined	11.5	47.2		52.8	90.0	
Togo	11.3	49.6		54.9	90.3	

31. It is noted that in the above Table II the water soluble P₂O₅ conversion is not constant. This is largely due to the level of aluminium and iron impurities. The correlation between the Al and Fe level and the insoluble P₂O₅ is approximately:

- (i) Each part of Al₂O₃ in the acid/product will give 1.39 parts insoluble P₂O₅.
- (ii) Each part of Fe₂O₃ in the acid/product will give 1.78 parts insoluble P₂O₅.

The expected water soluble P₂O₅ in MINIFOS from a number of rocks is given in Table III below.

Table III Expected water solubility of MINIFOS

Rock Source	water soluble/total P ₂ O ₅ per cent dry basis
Florida calcined 75 EPL	92
Florida uncalcined 75 EPL	90
Florida uncalcined 67 EPL	88
Kola	95
Morocco 75 EPL	96
Taiba	94
Togo	91

VI. MONOAMMONIUM PHOSPHATE AS AN INTERMEDIATE FOR
COMPOUND FERTILIZER PRODUCTION

32. About one million tonnes per annum of MINIFOS is already produced in various parts of the world, listed in Table IV, and with plants in the construction stage the total annual production will be around 1.4 million tonnes.

Table IV

Country	Annual Capacity	Status
Australia	128,000	In operation
France	133,300	In construction
Holland	80,000	In operation
Japan	60,000	In operation
Sicily	133,300	In construction
South Africa	107,000	In operation
Spain	280,700	In operation
Spain	160,000	In construction
Spain	92,000	Projected
U.K.	195,300	In operation

33. Apart from the low capital investment for the process plant, there are other important economic and process reasons why considerable benefit can be derived from the use of this material. The main advantages are as follows:

33.1 The operating cost of MINIFOS plant is low and only about one quarter of the cost of producing granular ammonium phosphate in a conventional process.

33.2 MINIFOS can be stored in bulk and can be handled by all the conventional mobile and fixed handling equipment used in the fertilizer industry. The product is non-hygroscopic and free from fine dust. It can be recovered easily from bulk store and its storage properties compare favourably with other fertilizer intermediates and raw materials.

33.3 MINIFOS can be used to augment, or replace completely, single or triple superphosphate in the conventional NPK granulation plant. Its physical form makes it eminently suitable for use as an intermediate and it embodies all the advantages of a P_2O_5 carrier such as single or triple superphosphate in that it can be economically manufactured at a large central site and distributed cheaply by bulk carrier to satellite granulation plants, but with the added advantage that it carries around 65 units of water soluble plant food per tonne. Another important advantage of this material is that it is completely compatible with urea and ammonium nitrate whereas superphosphates are not particularly when water-soluble P_2O_5 is required. The manufacture of concentrated compound fertilizers based on MINIFOS and ammonium nitrate or urea is now being carried out successfully on the full scale. These products have good physical properties, and drying curves presented in figure 5 show that the fertilizer can be dried to give a low moisture content, ensuring good storage characteristics. Fisons and other companies throughout the world have incorporated MINIFOS into a very wide range of fertilizers, for example:

8-38-16	15-15-15
10-15-20	16-18-14
12-12-24	17-17-17
12-24-12	19-19-19
13-13-20	20-10-10
14-14-14	22-11-11

33.4 The use of powder MAP plays an important role in ensuring the maximum output from a granulation plant. Since the material contains a relatively small amount of water, its incorporation with other materials in conventional rotary drum granulation plants takes place with a fines recycle ratio which is determined by the efficiency of the granulation device rather than the need for liquid phase absorption. This is particularly so when the granulation step is liquid-phase controlled due to the presence of other soluble salts and water, and where the solution phase increases significantly with temperature. In these cases powder MAP has a big advantage over MAP provided in the form of a slurry from pre-neutralisation facilities. Recycle ratios in the range 1:1 to 2:1 are typical with the use of powder MAP. The replacement of part or all of the P_2O_5 component by powder MAP in slurry processes where the neutralisation of phosphoric acid is carried out "in situ", and recycle ratios of the order 3:1 to 8:1 are typical, results in a considerable increase in output with only minor modifications to the plant. The granulation curves in figure 6 relate temperature to water content in the granulator for concentrated 1-1-1 ratio compounds based on MAP, urea or ammonium nitrate and potash. It can be seen that the granulation condition is very sensitive to both water and temperature, so that the effect of feeding a cold MAP powder into the granulator, as compared with a hot MAP slurry containing three or four times the quantity of water, can greatly reduce the recycle requirement. This type of granulation curve can be used together with the heat and water balance across the plant (6, 7) to calculate recycle ratios for differing products and production conditions. These results have been completely checked in practice from full scale operating data and show that when producing concentrated fertilizers based on ammonium nitrate and powder MAP, the recycle requirements are about one third of those when ammonium nitrate and slurry AP are used. In the case of fertilizers based on MAP and urea the advantage of using MINIFOS is even greater and this reduction in recycle ratio naturally results in much lower equipment and operating costs.

33.5 MINIFOS can be further ammoniated if required to produce diammonium phosphate either as a straight fertilizer or in compound fertilizers. Very rapid and efficient uptake of ammonia is obtained in the granulator and mole ratios of $\text{NH}_3:\text{H}_3\text{PO}_4$ of 1.9 to 1 are easily attained with recycle ratios of less than half the normal TVA-type process. The MAP solution can be directly sprayed into a rotary granulator, together with other raw materials to make NP, NPK, MAP or DAP granular fertilizers.

33.6 Perhaps one of the most important considerations which enhances the attractiveness of solid mono-ammonium phosphate intermediate is the simple nature of the consumer granulation plant. It has already been said that the MAP manufacturing process does not need expensive ammonia recovery equipment. This also applies to the NPK granulation process. Furthermore, the use of MAP does not limit drying temperatures, so that lower product water contents can be obtained much more readily than with fertilizers containing di-ammonium phosphate. This is becoming an extremely important consideration as the increasingly high standards for product storage become prevalent. In the U.K., for instance, it has become necessary for granular fertilizers to be stored for periods up to nine months before use, due to the very uneven market conditions. Fertilizers such as 17-17-17 for example need to be dried to less than 0.3 per cent in order to obtain satisfactory storage properties.

34. One of the most important groups of fertilizers during the next few years, especially in the Middle and Far Eastern areas (8), is likely to be the urea-ammonium phosphate and urea-ammonium phosphate-potash system. Hignett (9) and others have urged this probability for some time on the broad basis that these products have an exceptionally high nutrient content, are agronomically acceptable in these particular areas, and are free from burning or explosion hazards. There are, however, two other factors which are significant but do not

appear to have been developed seriously as yet.

35. Firstly, there already exists in the "emergent" areas of the world a considerable internal urea capacity. This capacity will be augmented within the next few years by plants already under construction or in the last stages of planning. Urea has become and will continue to be a principal form of nitrogen plant food. The reasons for this are clear: urea is the cheapest and most concentrated form of solid nitrogen available, it is agronomically effective, and the basic raw material is frequently indigenous.

36. Secondly, and probably due to the situation mentioned above, the manufacture and use of phosphatic fertilizers has lagged behind that of nitrogenous fertilizers. There is now a growing understanding that properly balanced complete fertilizers are essential to the proper crop yield and also to obtain the maximum value for each plant nutrient. Some urgency now exists to redress the balance. In this respect the evaluation of the most appropriate process routes for compound NP and NPK fertilizers should take account of the existing or planned nitrogenous fertilizer capacity in that area. As an illustrative example it is useful to consider the fertilizer industry in Pakistan. After the completion of the third 'five year plan' proposals, which involve a very considerable nitrogen expansion, the country's requirements will be essentially satisfied for some years to come, with the exception of the requirements for phosphate. This need has now become fully realized by the relevant Organisations and Agencies within and outside Pakistan, and various basic schemes for at least minimising the phosphate deficiency by means other than import of finished fertilizers are being discussed. Analogy with European history shows that the most viable and useful routes will be those which offer the phosphate plant food in combination with nitrogen and, later on, potash.

37. Of the various routes available, the urea-ammonium phosphate system appears to have the most attractive advantages. The urea-superphosphate system suffers from the fact that the two components are basically incompatible and special techniques are necessary if a high P_2O_5 water solubility is to be maintained in considering the urea-ammonium phosphate system it is

assumed that urea is available as a solid, crystalline or prilled. Urea is available now from many parts of the world and can be regarded as a fairly readily available intermediate in solid form. The nitro-phosphate route requires additional installation of nitrogen capacity and therefore cannot assist the basic problem of nitrogen-phosphate imbalance. Apart from this, there are other serious disadvantages of the process.

38. TVA has carried out extension development work on methods for producing urea-ammonium phosphate fertilizers and much of this has been published (10). Fisons Limited has also carried out research and plant work on this system with particular reference to the use of MINIFOS as the phosphate donor (11). Briefly, this work has shown that the granulation of solid urea with MINIFOS and, as required, potash can be carried out in the Fisons conventional granulation process with only modest alteration. The granulation step can be operated at a recycle ratio in the range 1.5-2:1. Drying rate experiments have shown that this step in the process is easier to accomplish than with ammonium nitrate based fertilizers even though reduced temperatures have to be used because of the lower melting point of the urea-ammonium phosphate system. Product storage and hardness properties are as good as those of equivalent fertilizers based on the ammonium nitrate-ammonium phosphate system. When MINIFOS is used, there is no measurable ammonia loss and the process is therefore much simplified by the absence of ammonia recovery equipment.

39. A scheme showing how powder MAP could be used to build up the granular N-P requirement for a country such as India where phosphate in one form or another has to be imported is shown in figure 7. For comparative investment and operating costs purposes a scheme representing a somewhat different but frequently discussed route involving phosphoric acid transport, presented in another paper (8) is also shown. In both cases it is assumed that a phosphoric acid manufacturing unit is situated at a large phosphate rock mining area such as Florida or Morocco. The basis of the costing is 300,000 tpa of compound 27-27-0 and 290,000 tpa of compound 28-28-0, equivalent to 84,000 tonnes of imported P_2O_5 .

39.1 In the powder MAP route there is no extensive phosphoric acid

storage, since the wet process acid is immediately converted to powder intermediate without the need for clarification and shipped by conventional sea transport to the consumer country where it is incorporated with urea and perhaps potash in a simple granulation plant such as that operated by Fisons. The alternative route necessitates the transport of phosphoric acid in specially constructed ships with little likelihood of suitable return cargoes being available. This form of transport has not yet been carried out on the scale needed for the size of consumer factories now envisaged. It would certainly be necessary to utilize clarified acid in order to minimise settling during transport. Large and expensive phosphoric acid storage facilities are required at both terminals. Furthermore, the consumer granulation plant needs phosphoric acid neutralization facilities and extensive ammonia recovery equipment which are expensive. The operation of this type of plant is also more complex.

39.2 Investment, operating costs and savings have been calculated for these two routes based on data available in 1969 (8) and shown in Tables V, VI, VII. The difference in investment and transport costs is due mainly to the lower investment required for storage and transport of P_2O_5 as solid ammonium phosphate. The results of Table VII show that there is considerable benefit to be gained by transporting and using MAP powder for the manufacture of compound fertilizers in India as compared with wet-process phosphoric acid. Savings in investment and direct operating costs have been calculated and in order to estimate the total savings it is assumed that the cost of servicing capital would be about 22½% per annum to allow about 10% profit, 7½% depreciation and 5% maintenance. On this basis the savings are about £5.5 per tonne of P_2O_5 imported and more than £2 per tonne of compound fertilizer produced.

39.3 In the assessment it has been assumed that ammonia would be available at the same price in India and in Florida, but no allowance has been made for the transport of nitrogen carried as an ingredient of MAP powder. In certain cases this could represent a further advantage in favour of MAP if in fact, as is likely, ammonia in India is more expensive

than it is in Florida. Also, if it is necessary to transport the P_2O_5 intermediate within India from the point of unloading to another site then the powder MAP will show further advantages. These savings together with the ease and simplicity of handling transporting and using MAP powder could be very attractive to both producers of P_2O_5 in Florida and elsewhere, and to potential fertilizer manufacturers in India and elsewhere.

TABLE V COMPARATIVE INVESTMENT AND DIRECT OPERATING COSTS FOR IMPORTING 84,000 TPA P₂O₅ FROM ALGERIA TO INDIA

	54% ACID ROUTE			POWDER MAP ROUTE		
	Investment Cost \$	Investment \$/tonne P ₂ O ₅	Direct Operating Cost \$/tonne P ₂ O ₅	Investment Cost \$	Investment \$/tonne P ₂ O ₅	Direct Operating Cost \$/tonne P ₂ O ₅
FLORIDA SITE						
Concentration	270,000	3.24	1.51	160,000	1.90	1.51
Clarification	85,000	1.01	0.15	-	-	-
MINIPOS production	-	-	-	90,000	1.07	0.10
Phosphoric acid storage	550,000	6.55	-	-	-	-
KINLOS Storage	-	-	-	125,000	1.50	-
Asonis Storage	-	-	-	162,000	1.93	-
Terminal Facilities	20,000	0.24	0.10	160,000	1.90	0.30
Transport cost	-	-	15.00	-	-	10.40
INDIA SITE						
Terminal Facilities	20,000	0.24	0.10	250,000	2.98	0.50
Phosphoric acid Storage	550,000	6.55	-	-	-	-
MINIPOS storage	-	-	-	185,000	2.20	-
Importation cost of P ₂ O ₅	1,495,000	17.80	17.16	1,192,000	14.19	12.38

TABLE VI COMPARATIVE COSTS FOR COMPOUNDS BASED ON UREA AND AMMONIUM PHOSPHATES

	54% ACID ROUTE			POWDER MAP ROUTE		
	Investment Cost £	Investment £/tonne product	Direct Operating cost £/tonne product	Investment Cost £	Investment £/tonne product	Direct Operating cost £/tonne product
<u>27-27-0</u> compound based on urea and MAP - 300,000 tonnes/yr						
Ammonia storage	162,000	0.54	-	-	-	-
Urea Storage	125,000	0.42	-	125,000	0.42	-
Granulation Plant	816,000	2.72	1.05	600,000	2.00	0.70
Importation cost of P ₂ O ₅	1,495,000	4.98	4.62	1,192,000	3.97	3.34
Total Comparative cost	2,598,000	8.66	5.67	1,917,000	6.39	4.04
	54% ACID ROUTE			POWDER MAP ROUTE		
<u>28-28-0</u> compound based on urea and DAP - 290,000 tonnes/yr						
Ammonia storage	268,000	0.92	-	162,000	0.56	-
Urea Storage	125,000	0.43	-	125,000	0.43	-
Granulation Plant	936,000	3.23	1.10	605,000	2.08	0.57
Importation cost of P ₂ O ₅	1,495,000	5.15	4.80	1,192,000	4.11	3.47
Total Comparative cost	2,824,000	9.73	5.90	2,084,000	7.18	4.34

TABLE VII

SAVINGS WHEN TRANSPORTING AND USING MIXTOS FOR
THE MANUFACTURE OF COMPOUND FERTILISERS

	Investment £	Investment £/tonne	Direct Operating Cost £/tonne	Total Savings* £/tonne
Importation of P ₂ O ₅	505,000	3.61	4.78	5.59
Manufacture of compound 27-27-0 (urea and N.P.)	681,000	2.27	1.63	2.14
Manufacture of compound 28-28-0 (urea and DAP)	740,000	2.55	1.56	2.13

* To estimate the total savings it is assumed that the cost of servicing the investment would be about 22% per annum to allow about 10% profit, 7% depreciation and 5% maintenance.

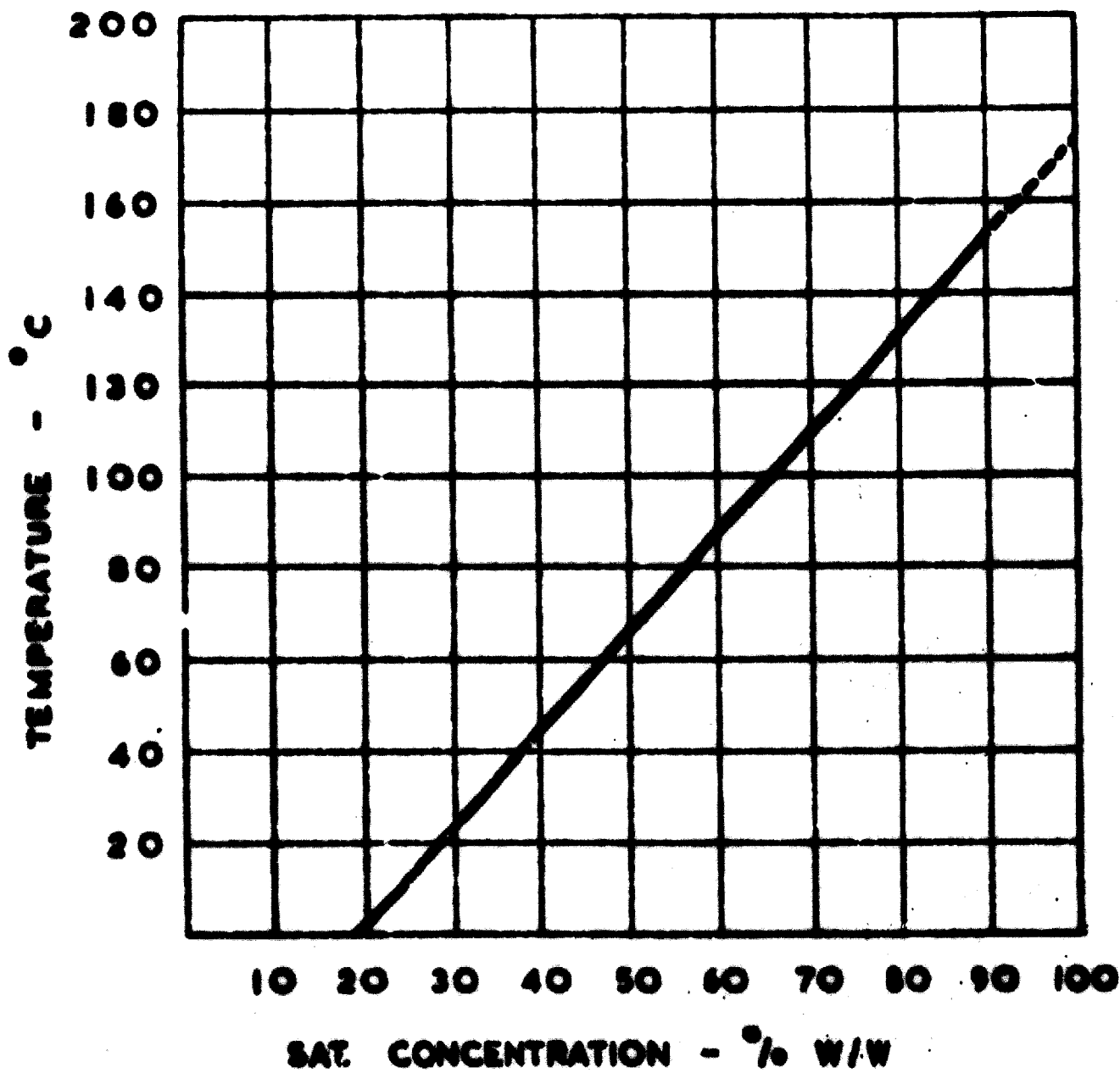


FIGURE 1
SOLUBILITY OF MONO - AMMONIUM PHOSPHATE
IN WATER

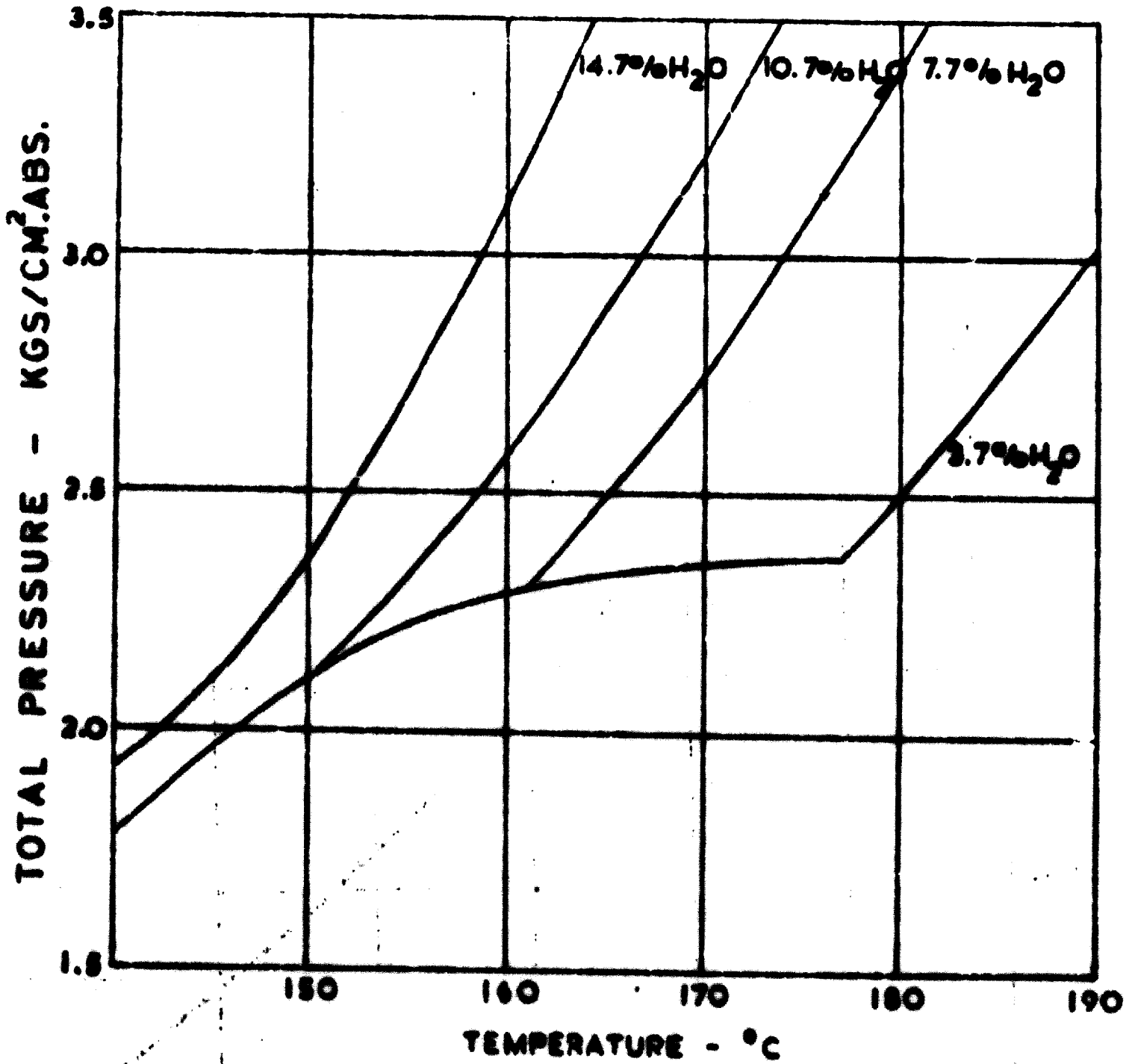


FIGURE 2

VAPOUR PRESSURE OF MAP - H₂O SYSTEM

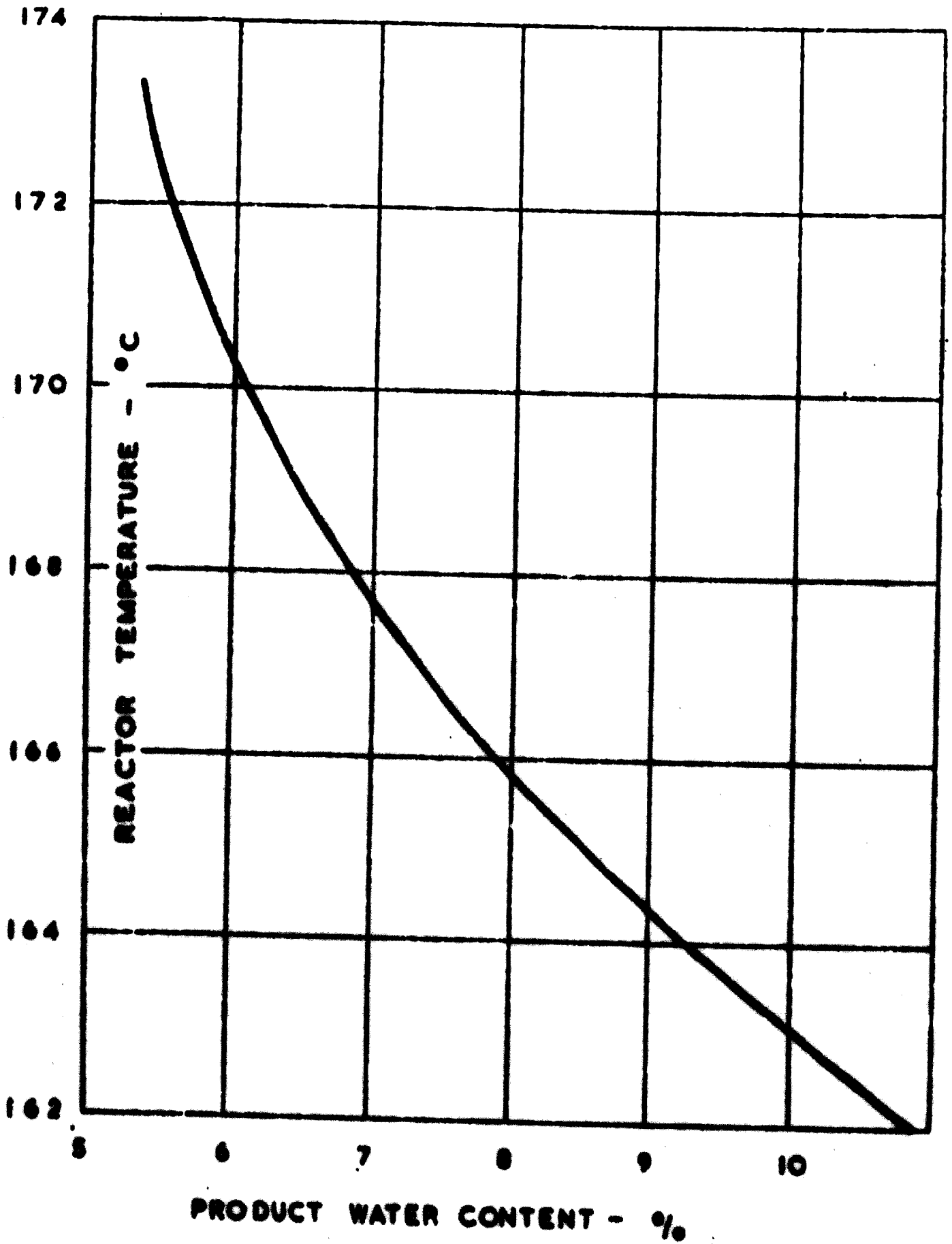


FIGURE 3
EFFECT OF REACTOR TEMPERATURE
ON
PRODUCT WATER CONTENT

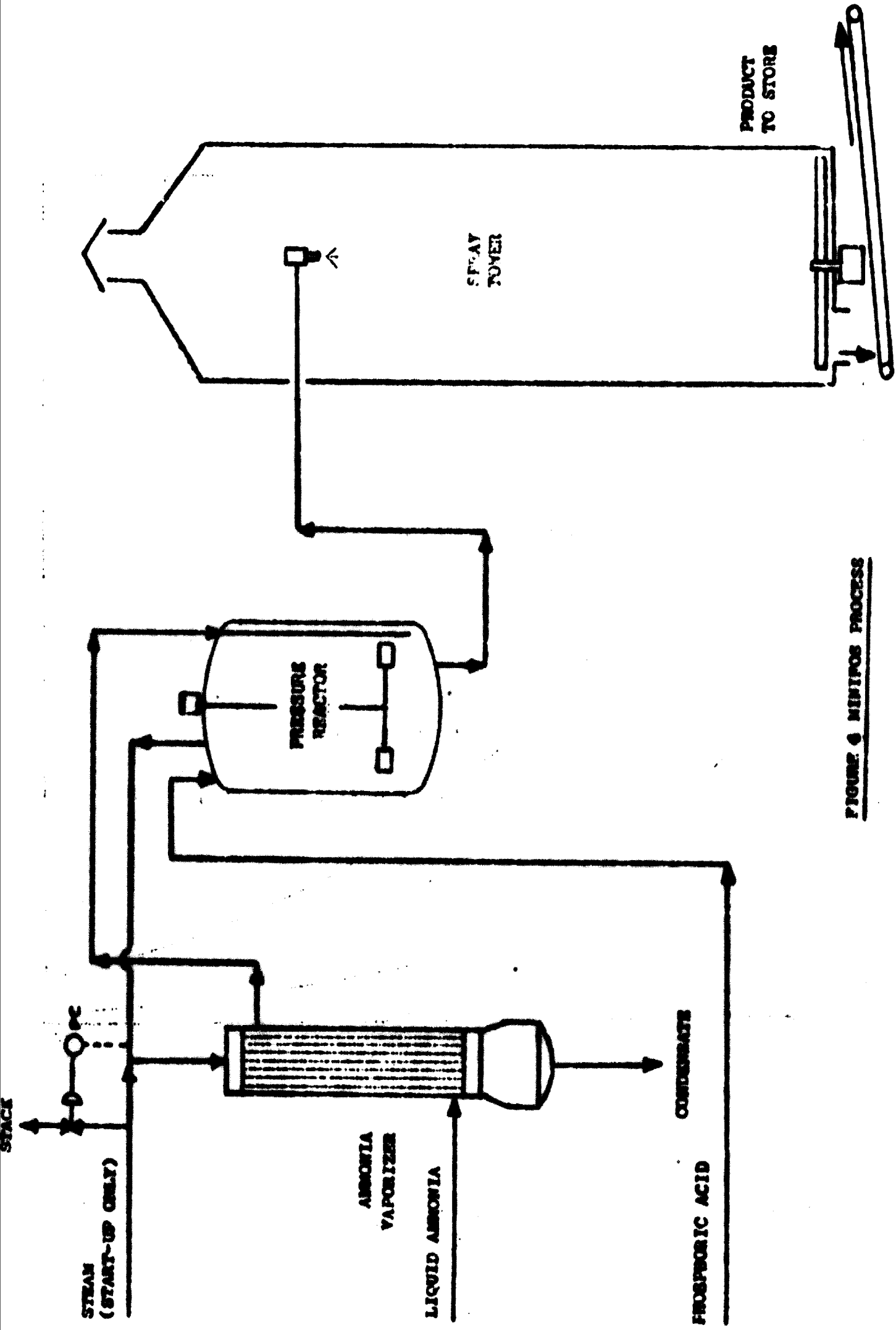


FIGURE 6 NITROS PROCESS

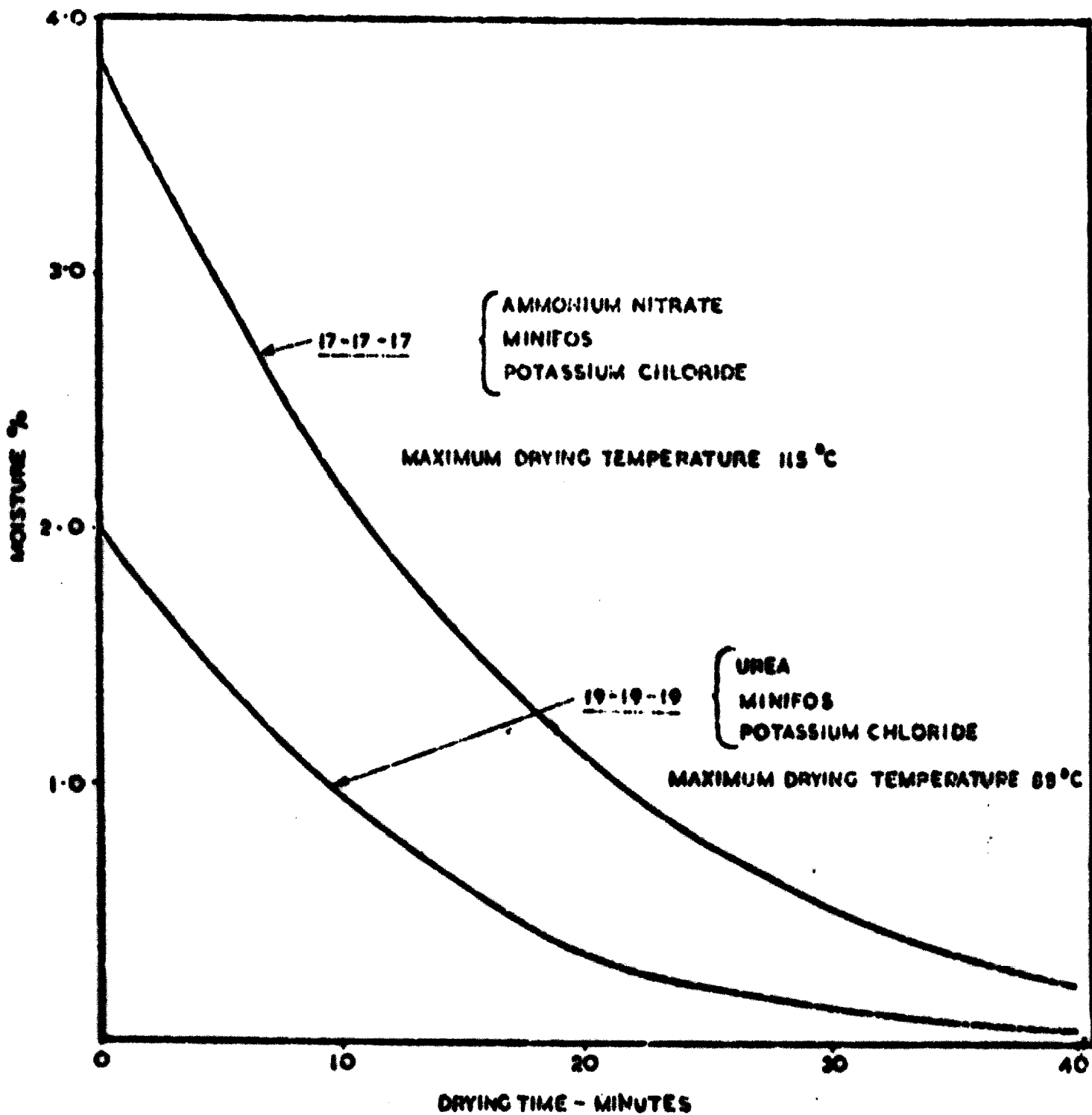
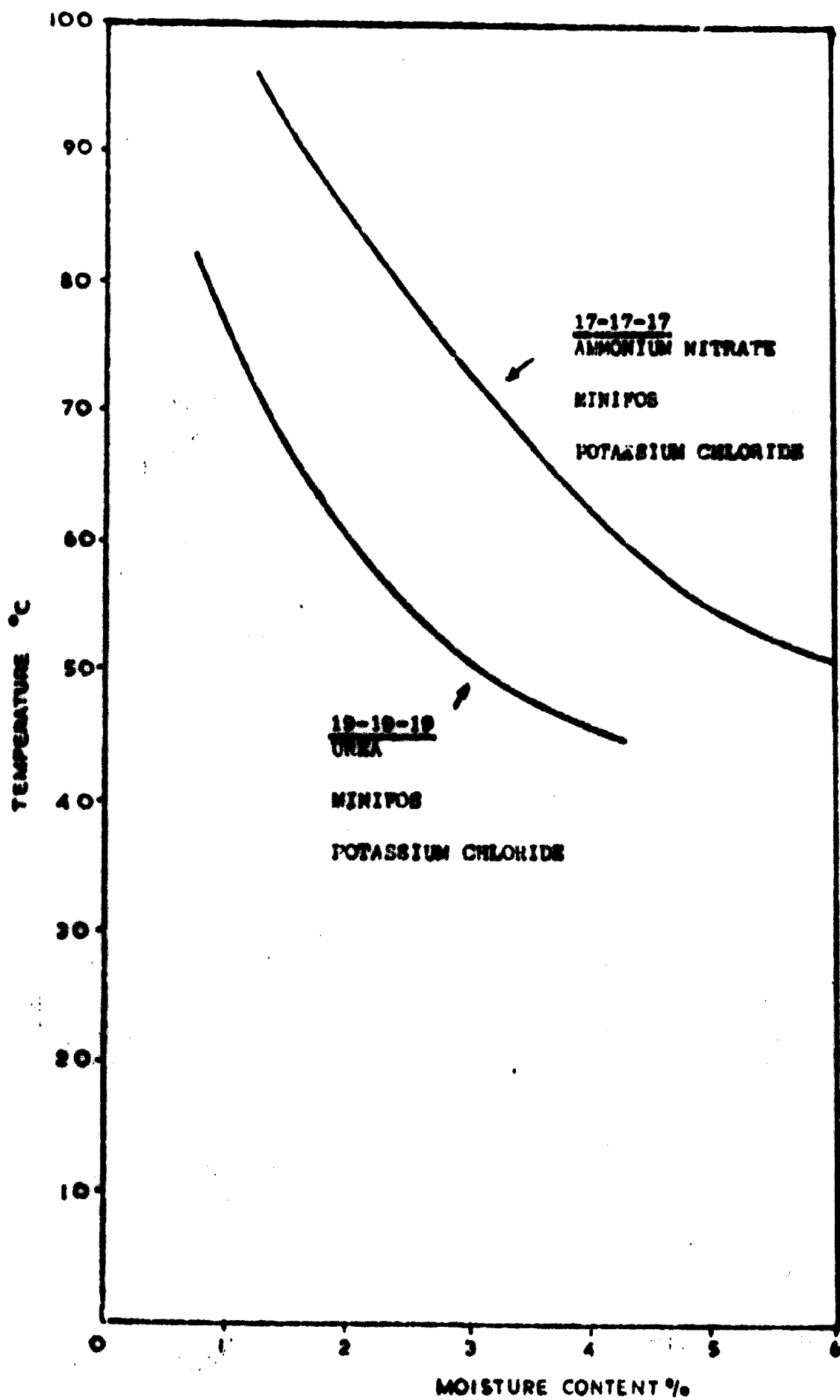
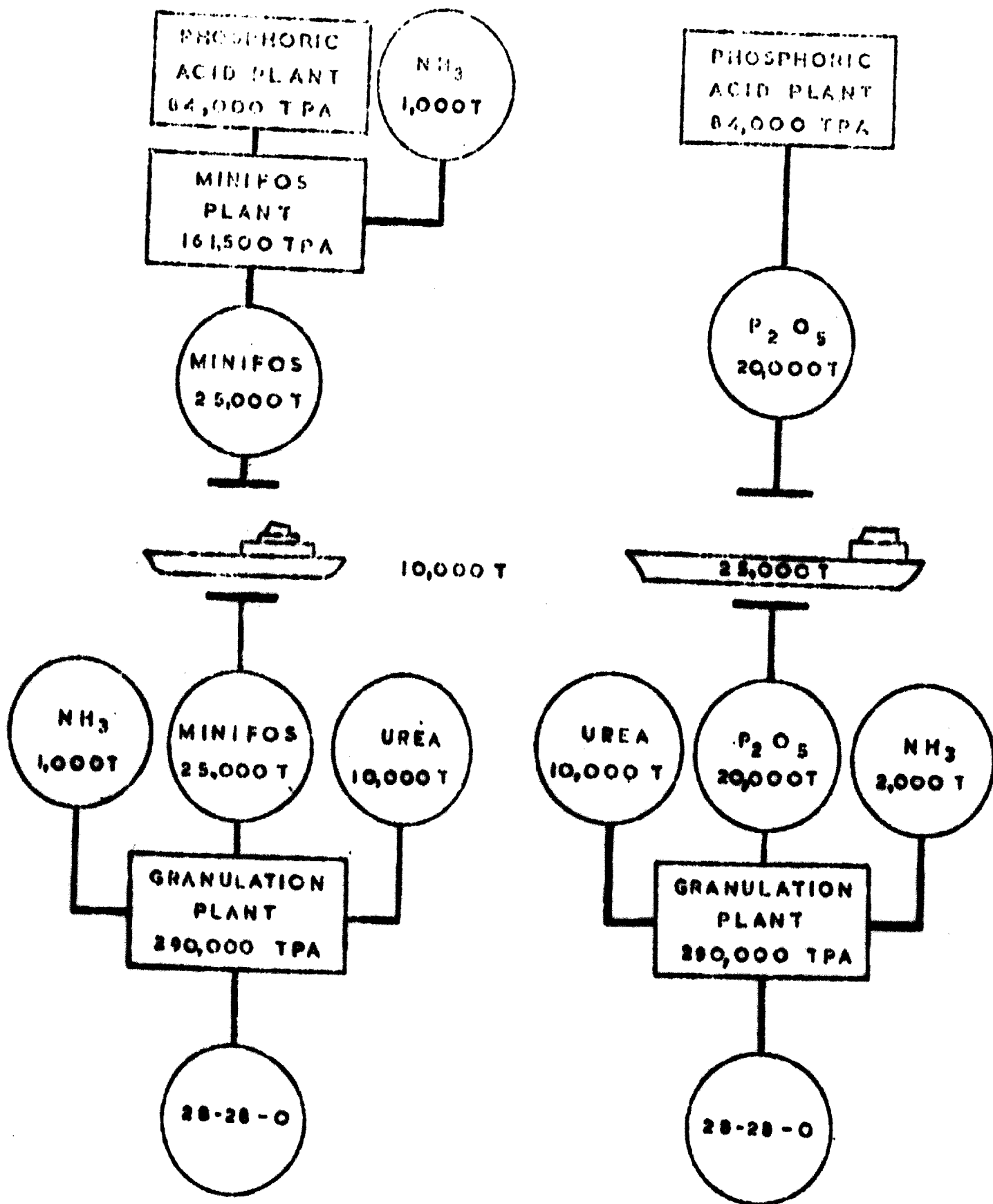


FIGURE 8 DRYING CURVES FOR COMPOUNDS BASED ON MINIFOS



**FIGURE 6 GRANULATION CURVE FOR COMPOUNDS
BASED ON MINIFOS**



FERTILIZER ROUTE

FIGURE 7

ACID ROUTE

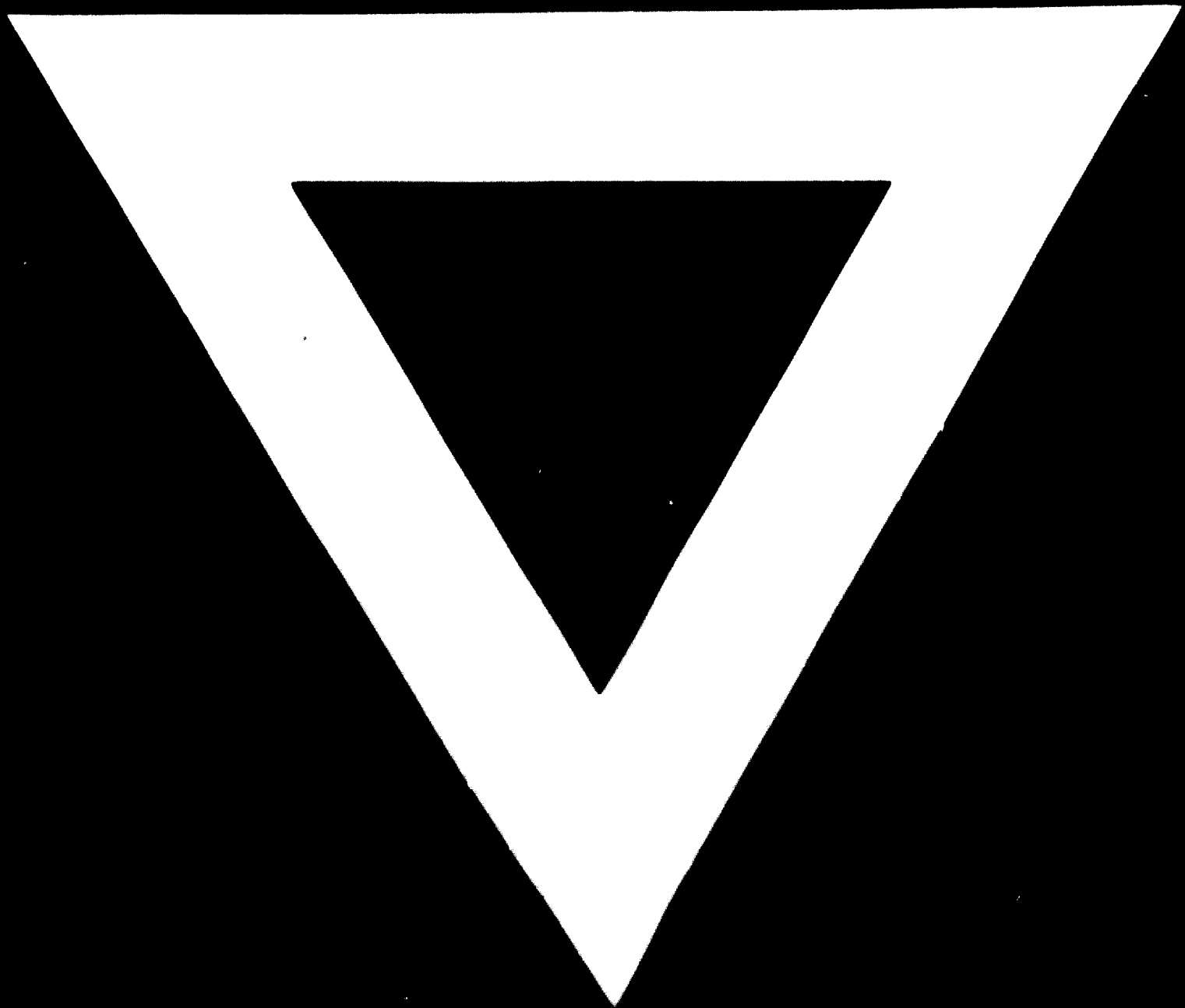
ALTERNATIVE ROUTES FOR P₂O₅ TRANSPORT

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14. 3. 72