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FIFTY YEARS OF PHOSPHATE PROCESSING TECHNOLOGY OR "THE BONES OF PHOSPHATE TECHNOLOGY"

by
Paul A. Smith, Société Chimique Prayon-Rupel, Belgium **and**
John Sinden, JEATECH, Brazil

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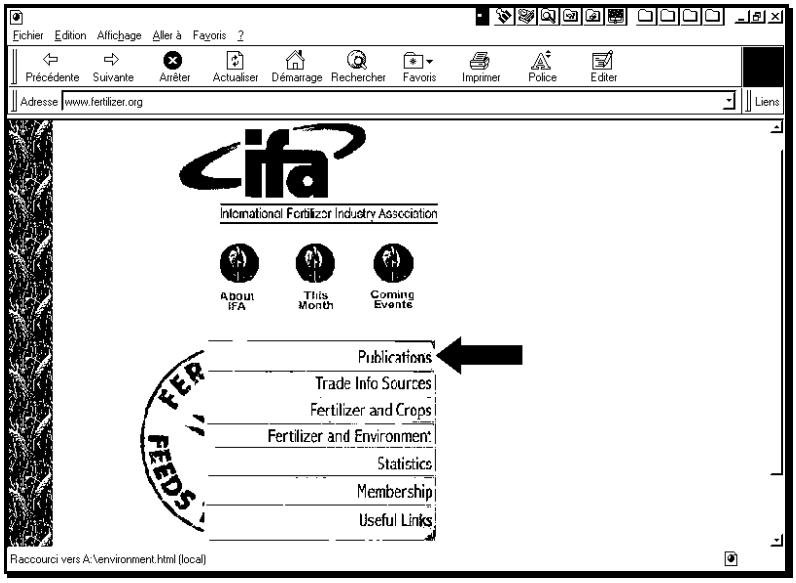
Introduction

When the proposal of an Exceptional 50th Anniversary Technical Conference was initially mooted, the idea of a visionary presentation on potential technological developments that could be expected in the future was envisaged. Although this type of analysis may well be applicable to nitrogenous fertiliser technology, the utilization of such an approach in the case of phosphate and granulation technologies must be doubted due to the difference in the basic technological concepts.

This presentation shows without doubt the contribution the ISMA/IFA Technical Conferences have made to the dissemination of technology for the benefit of all.



Many people in the industry still believe that a certain part of phosphate & NPK technology is "artisanal", this is certainly not true as today's understanding of the chemical and physical processes is better than ever. This still does, however, not allow the "gurus" of today to develop computer programs that may be used blindly by the future generations. The main basis for a good understanding is a rigorous technical base combined with a detailed knowledge of the practical experience already gained by the industry. Of the young engineers arriving into the industry today although most are conscientious, technically competent & computer literate some of them lack the desire to read books and articles but prefer to "surf the net".

Now their dreams have come true, the IFA Information Service has put all the papers presented at the ISMA/IFA Technical Conferences into an index and this can be accessed via the IFA Web Page **http://www.fertilizer.org.** Access to the index could be no simpler, on opening http://www.fertilizer.org the "Home Page" of IFA appears as shown above, one "*click*" on "Publications" reveals the publications page (Figure 1) and one more "*click*" on "IFA Technical Papers" reveals the full Index, see Appendix 1. An *off-line* "key-word" driven search engine exists to

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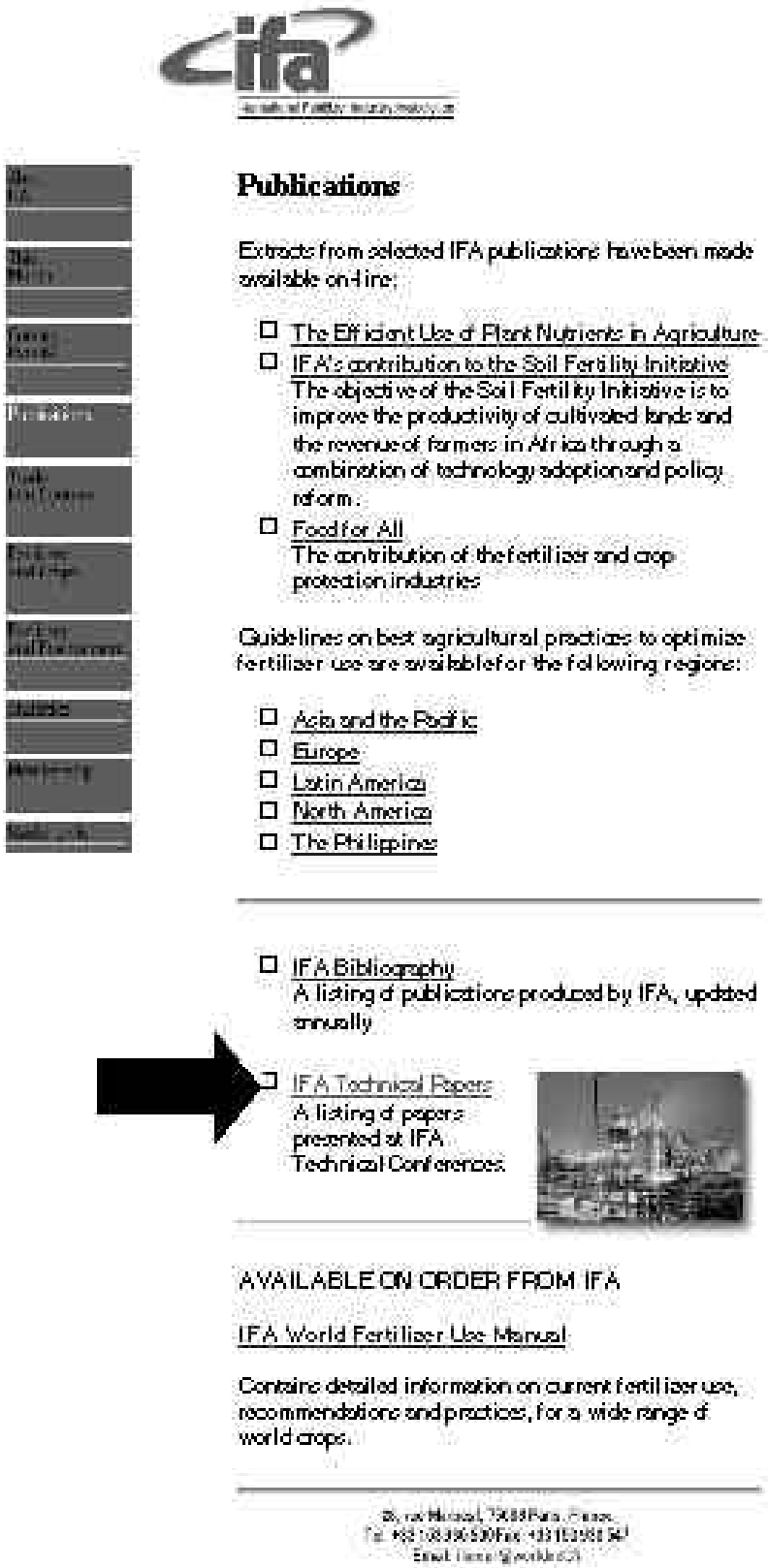
assist them to find articles pertinent to specific subjects easily. This service is accessible to member organizations through the sending of a simple ***e-mail*** containing the relevant "keywords" addressed to the IFA Information Service. Another excellent index is that of the "Proceedings of The Fertiliser Society"[1] that also contains many interesting articles on Phosphate, Phosphoric Acid and NPKs some of which are referred to in this article.

Figure 1 - Publications Page



Structure

The IFA Information Service has taken a considerable time in creating a data base of all the papers presented at the 25 Technical Conferences already held (the latest issue being “Index of ISMA/IFA Technical Conferences 1947-1996”) and this in itself is a very useful tool for the “apprentice” in the phosphate field. The aim of this presentation is to assist these newcomers by giving an insight into the gems of information contained in these “ancient texts” in order to stimulate the use of this “history” and prevent the reinvention of the wheel. The articles mentioned in the following texts are not intended to be exhaustive but have been selected solely to show how much useful information is available from this source.

The first part of the paper dealing with **Phosphates and Phosphoric Acid** was written by Paul. A. Smith and the format of this Index will be followed as a basis for the structure of this article and a marked up version of the Index with the papers in each section numbered from “a” through to “z” and then “A” through to “Z” is attached as Appendix 1 to aid cross referencing of this paper to the articles.

The second part, dealing with **Superphosphates and Granulation**, was written by John Sinden and will discuss some of the classic papers presented on this subject.

A. Phosphates and Phosphoric Acid

by

Paul A. Smith

1. Phosphates

1.1 Characterization of phosphates and pilot-plant testing

Many papers deal with the aspect of phosphate structure and the effect on “reactivity” (See Appendix 1 - 1.2.d, 1.2.e, 1.2.f, 1.2g & 1.2.x). However, one must always treat the aspect of “reactivity” with some caution. “Reactivity” applies to the potential reaction rate under ideal conditions. This is useful for the reactions in the production of TSP when the effect of particle size is duly considered but the effect of “coating” when the sulphate ion is present makes this data meaningless for reactions related to SSP and phosphoric acid manufacture. The article 2.1.j in the section Phosphoric Acid has an excellent treatise with respect to “coating” of igneous phosphates.

Other papers deal with the subject of pilot-plant testing for phosphoric acid manufacture. The most interesting paper on this subject, actually classified 2.1.z, dealing with the comparative results of a pure phosphate “spiked” with various naturally occurring contaminants. A further paper on this subject was presented at the IFA/CNCCC meeting in Beijing in 1983 (“Selective flotation of apatite from carbonatite glimmerite ore and use of this concentrate for phosphoric acid production at the Siilinjärvi plant and mine of Kemira Oy, Finland”).

Also at this Beijing conference there was an excellent presentation by N. Robinson "Procedures to Evaluate Phosphate Rocks for Phosphoric Acid Manufacture" that complemented a first paper classified as 2.1.p that was presented in Orlando and another presented at the ISMA/ANDA conference in São Paulo in 1975, "Laboratory and Pilot-plant Assessment of Phosphate Rocks for Phosphoric Acid and Ammonium Phosphate Manufacture".

Within this particular section, 1.2.p studies the effect in pilot-plant of higher MgO levels whilst the paper 1.2.r although not totally rigorous does contain some interesting details. Pierre Becker also presented a paper on the pilot-plant study of corrosion which was classified 2.1.t.

1.2 Phosphate selection

The selection of a phosphate for phosphoric acid manufacture is a very important decision. The level of beneficiation in a mine site case affects the overall production cost whilst in the case where the client buys his phosphate on the world market, it is important to choose the one which gives him the lowest production cost and a product quality that is acceptable. The first paper, which has some very interesting points, was 1.2.h. by M. H. Hampton of SAI. This was followed by that of the Italians presented in Orlando, 1.2.s and that of Hallsworth & Enriquez 1.2.v. Another paper classified 2.1.f gives Rhône-Poulenc's views on the subject but there is one error as it is the CaO/P_2O_5 that gives the guide to sulphuric acid consumption after the efficiency has been taken into account. Some of the aims of the beneficiation process to produce an optimum quality are set out in the Jordanian papers of Hummadi et al 1.2.C and Ghoseh et al 1.2.E and also 1.2.F by Guedri & Lahmadi.

2. Phosphoric Acid

2.1 General processes - dihydrate processes

2.1.1 Early technology

At the first conference held in Landskrona in 1947, a paper classified 4.2.a deals with SSP and TSP but states that the Belt-filter was invented by Wallny and some sketches are included of the original machine used in phosphoric acid. This article was complemented by a paper presented by Union Chimique Belge & Saint Gobain at the 1949 conference in Milan dealing with the Landskrona belt-filter, mechanical defoaming, agitation and reaction volumes, 1.3 m^3/t Gafsa/hour). The paper, 2.1.b presented by the Italians in Milan was the first to discuss the insoluble loss and the soluble loss. The insoluble loss was 3% and using three countercurrent drum filters with intermediate repulping a filtration efficiency of 98% was obtained. Also the reduction of corrosion due to higher levels of molybdenum in stainless steel was first noted.

Sven & Ralf Nordengren in 1953 at the Cambridge conference covered the aspects of temperature control, slurry recirculation, mechanical control of foam by agitation in the paper classified 2.1.d but the most important fact was the admission that an "overall" efficiency of a unit, when "accidental losses" were considered, was only of the order of 80-90%. It is still true today that "housekeeping" is still a very important factor in maintaining a high overall efficiency.

At the Aarhus conference in 1955 the pioneer utilization of flash-cooling was mentioned by Beetz & Jadot of Prayon (2.1.e) giving a figure of approximately 1 tonne of water being evaporated per tonne of P_2O_5. This paper also gave the other principles of the first generation of the Prayon process and stating that industrially an attack efficiency of 97% and a filtration efficiency of 99% were possible giving an overall process efficiency of 96%.

2.1.2 Insoluble losses

The splitting of the insoluble loss into two parts was also mentioned for the first time by the pair from Prayon in paper 2.1.e. They stated that if washed gypsum (free of water soluble P_2O_5) was extracted in a large excess of water part of the "insoluble loss" dissolved, the balance being unreacted phosphate. This method is still used by Prayon to determine the co-crystallised loss. This was a breakthrough as prior to this the conditions to minimize the insoluble loss could not be defined.

Further studies of the split of “insoluble loss” were made by Fröchen & Becker in 2.1.h at Stockholm in 1959 where it was surmised that the more soluble part of the insoluble loss was di-calcium phosphate trapped in the calcium sulphate lattice.

These discoveries of the 1950’s showed the key to optimization of the operation of a phosphoric acid plant reactor, it is a shame that here on the verge of the millennium many factories still do not check the split of the insoluble loss. The lattice loss or cocrystallised loss can be determined by various methods. Prayon dissolves the washed gypsum in an excess of water, Hydro dissolve in saline water (gypsum is more soluble in sea water) but most people, especially in the USA use the Citrate Soluble method and call the loss “the CS loss”. The CI loss (Citrate insoluble loss) is effectively the unreacted phosphate.

2.1.3 Transition - Dihydrate / Hemihydrate

It was also at the Stockholm conference, in paper 2.1.i, that the famous “Dahlgren curve” relating to the transition between dihydrate and hemihydrate was first published. This curve actually defined that the sulphate level affected the transition but sadly the people that later copied the curve left out this important factor.

The ease of conversion of Dihydrate to Hemihydrate is the basis of the Central-Prayon process (2.2.d, 2.1.c & 7.2.m) a unique process which first precipitates the calcium sulphate as gypsum separates off the product acid and then recrystallizes in hemihydrate to recover the cocrystallised loss. The added advantage is that if put to stack the hemihydrate absorbs the free water and produces a virtually dry, powdery dihydrate for immediate down-stream use as a building material.

The converse, recrystallization from hemihydrate to dihydrate, is not always so easy. Miyamoto of Nissan (1.2.P) stated that the conversion of igneous phosphates containing larger amounts of strontium cause the rehydration to be retarded and as such much larger conversion volumes are required.

Rehydration on the hemihydrate filter can be retarded by using additives as claimed by Fisons in 2.2.j but also mentions that fluosilicate scaling can be a problem in the strong wash section of the hemihydrate filter. Miyamoto also mentions this in 2.2.i.

2.1.4 Reactor design - Single tank v. multi-tank reactors

Sheldrick also presented a paper in Stockholm, classified 2.3.1.a, giving a mathematical treatise on the simulation of agitation and the advantages of multi-tanks over single tanks for reaction. This was extended to cover other aspects in the paper “Insoluble Losses in Phosphoric Acid Manufacture” presented by Janikowski, Robinson & Sheldrick to The Fertiliser Society in 19, Proceedings N°. 81[1]. Whilst in Edmonton in 1988 Robinson once again showed in paper 2.2.q that a multi-tank design, in this case in hemihydrate units, has considerable advantages with respect to dissolution when treating coarse phosphate feeds. This was also the basis of a Dorrco design to treat coarse phosphates as presented in 2.1.q where it was considered that the annulus of the basically single tank Dorrco unit could be compartmented to treat coarser phosphates.

The concept of single tank, high recirculation, iso-thermal, iso-sulphate conditions being the best design for crystallization was totally destroyed by the SIAPE presentation 2.1.D in Tunisia where they showed that having a zone within the recirculation loop at a lower temperature *improved* the filterability in the case of the SIAPE reactor on Gafsa phosphate.

The Rhône-Poulenc Diplo process (2.1.F) also showed advantages of using two reactors and splitting the reaction volume into two distinct zones but in this case the filtrates from the filter, the mother liquor and the strong wash, are recycled separately to create a P_2O_5 differential between the reactors. The fears of this type of process are principally in the inability to separate fluctuations on the filter from causing fluctuations in the reaction section.

The conversion of a single-tank unit into a multi-tank design and the resulting improvements is the basis of the paper presented by JPMC, 2.1.G in Amman, 1994.

2.2 Anhydrite / hemihydrate / hemi-dihydrate processes

2.2.1 Early technology

Early attempts to produce phosphoric acid whilst precipitating the calcium sulphate in the hemihydrate or anhydrite mode were fraught with problems (2.2.a, 2.2.b & 2.2.c) particularly due to the lack of attention to the critical state of water balance. In 2.2.c Hakansson claims a success but in paper 2.2.k the reconversion of the plant to dihydrate mode is discussed.

2.2.2 Dihydrate-Hemihydrate Process

The Central-Prayon process simultaneously producing a relatively high-strength (37% P_2O_5) acid and a merchant grade gypsum capable for use in plaster or cement / sulphuric acid production directly from the filter is covered in 2.2.d. The technological means to produce a high quality by-product gypsum being proved by this process. The sole problem being the relative size of the production of the gypsum and the size of the market for the off-take of such a product.

2.2.3 Hemihydrate & Hemidihydrate processes

The production of high strength acid in a single tank was studied by Rhône-Poulenc in 2.1.g but it was the article 2.2.e presented in Brussels in 1968 which is a classic in the control of crystallization producing a highly filterable hemihydrate and a strong (50% P_2O_5) acid. This was followed by the paper 2.2.f presented in Seville in 1972 which gave some light on the industrial results. The disadvantage of this single-stage process is the high co-crystallised P_2O_5 in the hemihydrate rejected and the sensitivity to accidental losses from the filter. Thus the Hemi-dihydrate process was rapidly developed and details of this process were first outlined in 2.2.g presented in Prague in 1974, followed by industrial experience presented by Lasovic et. al. in The Hague 1976 (2.2.j). In this paper along with that by Miyamoto, 2.2.I the problem of fluosilicate scaling in the down legs from the strong-wash section of the filter was highlighted. In the paper 2.1.C the extension of the Central Prayon process with the addition of a hemihydrate stage to produce strong acid is mentioned.

2.3 Other topics

2.3.1 Filtration

Although filtration is specifically referenced in only five papers, there are, in fact, many references in other sections. The paper 2.3.2.c compares the Giorgini travelling pan filter the Prayon filter and the UCEGO filter. The Giorgini method has been replaced by newer designs of belt filters and the Bird-

Prayon and UCEGO of today do not bear much resemblance to those of 1965. The modernization of a filter and the results on the overall operation of the reaction section is covered in the paper 2.3.2.e whilst paper 2.3.2.d covers the mathematical modelling of filtration and washing of gypsum cake. The paper presented by SIAPE on the use of flocculents is also of great interest, 2.1.m.

2.3.2 Concentration

Although the numbers have been scrambled so as not to give away the actual design figures the paper of Moraillon and Roubinet, 2.3.3.b covers many important aspects of the design of concentration units. The effect of tube velocity is covered, the need for the full de-superheating of the steam and the care that should be taken with the design of the condensate system are fully covered. The boosting of a unit in Florida is covered in the paper 2.3.3.e and the paper presented in Edmonton, 2.1.E deals with a new alloy used for the circulation pump. Submerged combustion is also covered, 2.3.3.c, in fact one of the few units still operating today is used for liquid fertiliser production at the Engis plant of Prayon.

2.3.3 Materials of Construction

I have never ceased to be amazed by the lack of papers on materials of construction. Operating companies would not really be giving away proprietary information and equipment and stainless steel suppliers should be keen to divulge their strengths but even so in fact only three papers are covered in this section 2.3.4. In 1949 Montecatini already noted that the addition of molybdenum is very favourable to the reduction of corrosion and in 2.3.4.a this is restated but including the fact that low carbon steels are more resistant to the wet process acid environment. The paper 2.3.4.b mentions the advantages of HV9A and Uranus B6 due to the higher molybdenum contents compared with the standard Alloy 20. Once again repeating the positive effect of low carbon and high molybdenum.

2.3.4 Effluents and Fluorine

Here I have grouped together the sections 2.6, 4.4 and 7.1. The most classical paper, 4.4.a, being that of Whynes and Dee presented in Cambridge in 1963. This paper already confirms the presence of the complex $H_2SiF_6 \bullet SiF_4$ and has some wonderful photos of drops coated with silica. The mole ratio of F:Si defines if the FSA produced will be perfectly clear or will have some solid silica in suspension. To have a clear solution the ratio must be greater than 5.0 and not 6.0 as might be suspected (H_2SiF_6) due to the formation of the compound $H_2SiF_6 \bullet SiF_4$. This is also mentioned in the Paper, 9.3.j, presented by Windmill in The Hague in 1976. Many papers deal with the evolution of fluorine from SSP/TSP units whilst the paper 2.6.g, presented by the Italians, mentions how FSA can be recycled to a phosphoric acid attack system. The paper 2.6.h deals with the F/SiO_2 ratio and its effect on the evolution of fluorine but one of the main modifiers to the fluorine balance is Al_2O_3 which forms the ion AlF_6^{3-} which holds the fluorine in the acid up to the concentration stage. Magnesium also has a similar effect but the actual ion formed has not been identified. Both Al and Mg linking with the fluorine make the acid less corrosive. The classic paper on fluorine recovery from evaporation units is that presented by Swift in 1963, nowadays more compact units to recover fluorine are being designed.

2.3.5 Gypsum

Many papers have dealt with the “gypsum problem”, there is in fact no problem at all in producing a merchant grade gypsum and phosphoric acid at the same time, the paper presented in 1988 at

Edmonton proves this, the only problem is that the market for this “co-product” is normally not sufficient to consume all the production. The use of gypsum to make sulphuric acid and cement was first mooted in 1949 but in fact the rules of physical chemistry have not changed over the years and this process still requires an enormous amount of energy to breakdown the gypsum.

3. Summary

I must apologise if I have forgotten one or two of the important papers but the aim was solely to whet the appetite and show what gems do exist. I hope that now some of the younger engineers will be convinced that to spend a few hours reading up on the past, with the aid of the IFA Information Service, will be minutes very well spent. Well that concludes the part on "Phosphates and Phosphoric Acid", this paper will now be followed by John Sinden’s contribution on "Superphosphates & Granulation".

B. Superphosphates and Granulation

by

John Sinden

1. Introduction

When first asked to co-author this paper I agreed that a paper such as this could be a stimulus to the younger members of the industry by showing how much useful information is already available in both the IFA Information Service and the "Proceedings of the Fertiliser Society", but it also brought back some vivid memories.

The first one, very early on in my career, concerned one of my managers. He said "John if you have a good filing system and a good memory very shortly people will start to take notice of how easily you solve the problems. This is because there really is very little that is new under the sun and the problems come round in circles. So it you know what happened last time it is easy". He also said that solving the problem was only half of the work the second half was reporting it to the right people.

The second memory is more recent, when I was Technical Manager for a major Brazilian fertilizer producer, when I became involved in a long discussion with the company’s President about what was the most economical conversion of the phosphate rock when producing single superphosphate. He was insisting on trying to achieve the highest possible conversion. The data which we were generating in the production control department showed that the highest conversion was not the most economical.

After several months of collecting more data and doing a large number of extra calculations it was finally possible to convince the President that he was wrong. By a strange coincidence several months latter I came across the paper 4.1.a which had been presented by P. Cambau at Landskrona in 1947. "Contribution to the Research of the Optimum Acidulation in the Manufacture of Superphosphates". To me for this personal reason this was a very important paper. It was one of the first papers to stress the economical aspects of the industry. It also must be one of the earliest examples of the now classic "J" curve of economics. It is interesting to note that this original work had been initiated by an apparent inconsistency. That was a that a SSP had been produced and sold with 1.5% insoluble P_2O_5 was more profitable than the SSP made with only 0.5% insoluble P_2O_5.

2. Phosphates and Superphosphates

2.1 Fundamental Concepts and Design Data

The concept of "Reactivity" as stated in section 2.1 is very different for the production of TSP and there is just as wide as difference between the effect of the sulfuric acid in the production of SSP and phosphoric acid. Of the papers which treat this subject (1.2.c, 1.2.d, 1.2.i and 1.2.B). The most important is 1.2.d and its complementary paper of the same title given as Proceeding nº 42 of the Fertilizer Society[1]. This treats the rock composition and source - sedimentary or igneous as the most critical factors.

Because of the large difference in construction costs of the superphosphate units and a phosphoric acid plants, it is normal for companies to build a superphosphate unit without carrying out extensive or any pilot plant tests. This is not the case for phosphoric acid units. These can be clearly seen from the titles in section 2.1 were there has been many papers on this subject.

2.2 Early designs of superphosphate units

In the first 14 years there were 17 papers on the manufacture of superphosphates as compared to 3 in the last 21 years. It is easy to see why ISMA became IFA. Of these papers; we have already discussed 4.1.a. The other papers which had significant effects and are still useful today were the papers 4.2.c, 4.2.c and 4.2.j which described the three main production processes. Two using easy to construct belt dens and the other describing the modifications to the more traditional slat type den. Today the simplest, the Etablissements Kuhlman linear belt den, having the lowest investment and maintenance costs has dominated the market in the countries which still make significant production of superphosphates - Brazil, Egypt, India, Australia, New Zealand and even the large plants in China.

The other processes such as were described in papers 4.2.i and 4.2.q have basically fallen by the wayside.

It is interesting to note that for such a significantly important commercial process the Kuhlman paper 4.2.d is very brief and tries not to give away practical details.

In this section there were papers (4.2.c and 4.2.p) devoted to controlling the production and how to calculate your production. This still remains a problem today, with a product which undergoes "curing" in the bulk product store - losing moisture and other gaseous components both of which are variable - as a more weighty product is of little use.

Papers (4.2.h) which was a work by the authors of paper (1.2.d) studied the process variables in the production of SSP in more detail. The paper also cited the problems of being able to analyze the products where the preparation methods used in wet chemical analysis seriously changes the chemical composition. The primary difficulties being with moisture content and free acidity. It is to be noted that the problems do not go away. The paper (11.t) was about the problems of the determination of moisture contents.

There have been very few papers about TSP, of these none were particularly significant, the first being a brief paper describing the possibilities of making the product economically (4.2.f) the other on how it was necessary for certain types of phosphates to use surface active agents to improve the physical properties and granulation characteristics (papers 4.2.n, 4.2.r and 4.2.t).

There was no paper comparable with the Fertilizer Society Proceedings nº. 21[1] "The Manufacture of Triple Superphosphate" by J.J. Porter and J. Frisken in 1953, which went into great detail on the subject.

2.3 Ammoniation of Superphosphate and Fluorine effluents

The remaining papers in section 4.3 and 4.4 deal with the granulation and ammoniation of the superphosphates and with fluorine effluents. Of these papers only (4.3.d) on the ammoniation and granulation could be considered significant, but since this work was carried out in UK which had at that time guaranties for phosphorus based on water solubility the degree of ammoniation was strictly limited.

Fluorine effluents have always been a part of the superphosphate story as the principal environmental concern. The papers, 4.4.a, 4.4.b, 4.4.c and 4.4.f, treated the chemistry of the system. The most important paper was 4.4.i which treated the recycling of the fluorine effluent by-product, the H_2SiF_6, back to the reaction system and to extinction. This was demonstrated by the Italians in this paper, which in the case of sedimentary phosphate rocks had the following advantages, reduction in the sulfuric acid consumption and the disposal of the by-product H_2SiF_6.

3. Granulation

It is going to be very difficult to limit this review to papers that only considered the granulation of phosphates so we have included some of the NP and NPK fertilizer granulation papers.

3.1 General

The following papers (5.1.f, 5.1.l, 5.1.m and 5.1.o) all made significant contributions to taking away some of the "black art" from the granulation processes. T.P. Hignett's paper described the various developments that had been made at the NFDC - TVA.

The 1976 meeting at The Hague was particularly rich in granulation papers (5.1.j, 5.1.k and 5.1.m) all being important in their different ways - 5.1.j being on a specific process route which used a mixture of potassium chloride, phosphate rock and sulfuric and phosphoric acid to make granular superphosphates and PK compounds in a single step process. The control of the system becomes very critical particularly in the drying section to avoid the formation of excessive amounts of hydrochloric acid gas.

The paper 5.1.l was for me a follow up paper by CROS S.A. on the applications of their pipe reactor. This time being used with urea to make high analysis - ceiling grade products such as 1:1:1 (19-19-19) at low cost and at relatively low recycle rates. This was directed at the uprating of the conventional regional type granulation plants based on solid raw materials.

The paper 5.1.m on the other hand described the advances carried out by Jacobs Engineering to the traditional high recycle slurry based routes to NP and NPK products. These plants were originally built in the phosphate region of central Florida but are also used in many other parts of the world. The new details included controlling the recycle and also improvements in the crushing of the oversize and obtaining an equilibrium between the dryer and granulator.

A common feature to all these papers was that they were all describing specific process routes and did little to explain the theory or mechanisms which lead to the granulation of the raw materials.

3.2 Ammonium Phosphates - Section 5.2 of the Index

Again the papers in section 5.2 "Ammoniation, MAP and DAP" are mainly descriptive of specific processes or process routes such as papers 5.2.d, 5.2.e, 5.2.g, 5.2.h, 5.2.i, 5.2.m, 5.2.n and 5.2.r or they concentrate on the effects of the impurities in the phosphoric acid in the product quality and/or production capacity - these were papers 5.2.o, 5.2.q and 5.2.s. There were fewer papers being directed towards the chemistry of the systems but these were more concerned about product quality, chemical and physical, rather than the actual processes of making good granules. In this category were papers 5.2.b and 5.2.j.

There was a general tendency for these process based papers to be related to product cycles. One of these cycles was the use of powder MAP as a substitute for superphosphates as a way of permitting the smaller regional granulation plants which had been designed to use basically solid raw materials to make higher analysis products without having to invest in storage capacities for the fertiliser liquids - ammonia - sulfuric and phosphoric acids.

Hence there are various papers discussing the relative merits of the different routes used to make powder MAP. During the late 1960's through to the early 1980's more than 40 of these type of plants were built in Europe, North America, North Africa, The Middle East and in many other parts of the world. Very few are still operating today, with even fewer number being built. The main use for these units today is that with the decline in the production of TSP they are one of the only routes capable of consuming the "sludge" from the clarification and purification stages of phosphoric acid production.

One of the more interesting papers in this section was presented in Paris (5.2.s). This was a pilot plant scale investigation into the effects of the impurities in the phosphoric acid on the production of DAP. The main impurities studied were iron, magnesium, aluminium and fluorine. It is interesting to note that the North American, and more specifically the Florida based companies, have a phobia about high levels of magnesium and their effects on both the production of the phosphoric acid and the DAP. One suspects that this study was carried out to confirm their suspicions about magnesium.

The conclusions of these tests were as follows:

I. Aluminium showed the most severe effect on operations. It also affected the DAP grade by decreasing to the ability to incorporate nitrogen thus decreasing the $NH_3 : H_3PO_4$ mole ratio. It caused more problems with viscosity in the preneutralizer, but improved the storage properties at high moisture levels.

II. Iron showed the most effect on nitrogen grade, but showed less effect than aluminium on a weight for weight basis on plant operation. It also adversely effect preneutralizer viscosities but not as much as aluminium. It caused some changes in the physical properties of the granular product.

III. Magnesium also lowered nitrogen grade but not as much as iron. The magnesium reduced the formation of citrate insoluble P_2O_5 and improved the neutralizer slurry viscosity! There were some negative effects on the products storage properties.

Section 5.3 deals with nitrophosphates which are outside the scope of this paper.

3.3 Special Techniques - Section 5.4 of the Index

In the section 5.4 of the Index some of the most important papers are classified. In the first section 5.4.1 - Reactors, each paper is once again more descriptive of specific process routes and equipment the most interesting papers being (5.4.1.a, 5.4.1.b, 5.4.1.d and 5.4.1.e). With paper (5.4.1.b) given by B.R. Parker of TVA at Orlando in 1978, details not only of process parameters but also some design parameters are given, but once again specifically for the equipment and not the mechanism of the granulation process.

In section 5.4.2. Granulation, there are several papers which helped demystify the granulation process. These include papers (5.4.2.d, 5.4.2.g, 5.4.2.m) while other papers on this aspect can be found in (9.2.h, 10.g and 10.k).

Besides these papers there were also the Fertiliser Society Proceedings[1] Nº. 47, 55, 59, 127, 215 and 310 - and another excellent paper was given by J.A. Benes at the IFA Middle East Regional Technical Seminar on NPK Fertiliser Technology in Aqaba in 1983. Of all these papers the one which is of special interest and importance is 5.4.2.e “Agglomerate Granulation as an Equilibrium Process” presented at the IFA Technical Conference in The Hague in 1976 by J.H. van der Leek. This paper not only treats and explains the relationship between the ratio of solid and liquid phases in the granulator but also treats the variations which can occur in drying process. It also explains effects that the efficiencies of the screens and the oversize crushers have on the process of granulation. It is obvious from the way J. Benes talked about van der Leek's paper in his various presentations that it had a major influence on the GPSM - Granulation Process Simulation Model that was developed at by UHDE G.m.b.h. and presented at various technical conferences. The first being “Design of Compound Fertiliser Plants with the Aid of Computer Models” IFA Regional Meeting, Aqaba 1983 and the latest paper 9.2.h “Modifying Existing DAP/NPK Plants to Comply with New Environmental Regulations”, Amman 1994. Basically the UHDE Benes' papers simplified the J.H. van der Leek's conception and theory on the agglomeration process. They introduced a "granulation factor - a" which was very easy to measure and this plus various series of screen analyses made it possible to evaluate the operation of a granulation plant and build a simple but accurate model of the granulation plant and process.

One of the earliest classic papers was given by at the Fertiliser Society by A.T. Brooks "Developments in Granulation Techniques" in 1957 Nº. 47. The basic change here was the use of steam instead of water as the granulation medium.

It went in to describe the effects of the particle size distribution of the raw material - the recycling average the distribution of the liquid phase and the rotation of the granulation drum.

The final paper would have to be paper (10.k) "Operating Experience with Phase Rate Based Control of the CAN/NPK Granulation" by P.B. Olsen of Kemira which was presented at The Hague in 1992. This is the view to the future using an expert system integrated to a Phase Rule Control System which allows the use of a DCS system to control the granulation process using fuzzy logic.

The system is supposed to be user friendly and as good as the best human operator.

4. Conclusions

Before writing this paper both Paul Smith and myself were convinced that the task would not be easy and that such a paper would be “very dry”. We both have tried to demonstrate, each in our own field, that extensive useful information is available in the annals of the IFA Information Service and that via the advances in information technology tracking down such information is easier than one might expect. I’m sure that we have both left out significant presentations but at least all people reading this document are aware of the depth of information available and may be stimulated to read at least one or two of the articles.

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   e-mail fertsoc@cjdawson.demon.co.uk
   Web site http://www.fertiliser-society.org

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o	Process Improvements in Manufacture of Wet Process Acid from Florida Phosphate Rock of Various Compositions.	A.N. Baumann, F.T. Nielsson, J.H. Surber and J.J. Yarnell. *Orlando, Florida, USA, 1978. Ta/78/6. 21p*.
p	Fisons' Experience on the Effect of Phosphate Rock Impurities on Phosphate Acid Plant Performance.	N. Robinson. *Orlando, Florida, USA, 1978. Ta/78/8. 15p.*
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s	A Route Saving Raw Materials and Energy Makes P_2O_5 Available through Wet Phosphoric Acid Process.	A. Davister and S.V. Houghtaling. *Orlando, Florida, USA, 1978. Ta/78/11. 13p*.

t	Factors Governing the Rate of Corrosion of Stainless Steels during the Production of Wet Process Phosphoric Acid.	P. Becker, M. Duthoit, M. Gauron and H. De Villele. *Vienna, Austria, 1980. Ta/80/1. 22p.*
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v	Bench-Scale Studies on the Use of Brazilian Phosphate Concentrates in the Production of Wet Process Phosphoric Acid.	M.A.C. Bruno. *Vienna, Austria, 1980. Ta/80/4. 11p.*
w	Improvement of SIAPE Process for the Manufacture of Phosphoric Acid in Order to Process Low Grade Phosphates with High Impurity Content.	SIAPE. *Vienna, Austria, 1980. Ta/80/5. 10p.*
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D	Thirty Years of the SIAPE Process for the Production of Phosphoric Acid by the Wet Process and Experience in the Revamping of Phosphoric Acid and Fertilizer Plants.	M. Essaba and Y. Louizi. *Port El Kantaoui, Tunisia, 1986. Ta/86/5. 30p.*
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b	The First Installation of a Phosphoric Acid Plant According to the Anhydrite Method at Vercelli, Italy.	S. Nordengren. *Aarhus, Denmark, 1955. Le/616. 22p.*
c	Full Scale Production of Hemihydrate Phosphoric Acid with 42% P_2O_5.	R. Hakansson. *Edinburgh, United Kingdom, 1965. Lee/65/2. 12p.*
d	An Account of Twenty Months of Phosphoric Acid Manufacture by a New and Original Process.	E. Pavonet and A. Davister. *Brusssels, Belgium, 1968. Lbe/68/1. 18p.*

e	The Production of 50% W/W P_2O_5 Phosphoric Acid Directly by Wet Process: Fisons Hemihydrate Process.	N. Robinson and S.M. Janikowski. *Brusssels, Belgium, 1968. Lbe/68/2. 22p*.
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j	Full Scale Operating Experience of the Fisons HDC Phosphoric Acid Process. Operational Experience in a Plant of 160 T/D at Rmhk Trepca (Yugoslavia).	V. Lasovic, M.L. Parker, N. Robinson, G.N. Quinton and P.A. Smith. *The Hague, the Netherlands, 1976. Ta/76/20. 25p*.
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p	Hemihydrate Operating Experience at Brunswick Mining and Smelting Fertilizer Facilities.	T. Gravestock. *Edmonton, Canada, 1988. Ta/88/17. 18p.*
q	The Prediction of Rock Dissolution Rates in the Norsk Hydro Hemihydrate Phosphoric Acid Processes.	N. Robinson. *Edmonton, Canada, 1988. Ta/88/18. 12p.*
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a	Fabrication de Superphosphate Double et d'Acide Phosphorique par Voie Humide: Etat Actuel et Possibilités d'Avenir.	S. Nordengren. *Milan, Italy, 25-26 September 1949. Le/ 158. 18p.*
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e	Farmland Hydro L.P. Increases Efficiency with 495 T/D Additional Phosphoric Acid Evaporator Capacity.	R.E. Biollat and J.M. Friedman. *Amman, Jordan, 1994. 9p.*

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b	The Use of Stainless Steels and Alloys in the Manufacture of Wet Process Phosphoric Acid.	J. Roubinet. *Helsinki, Finland, 1963. Lhe/63/13. 17p.*
c	Equipment Design Makes Both New Plants and Revamps Cost Effective as Regards Energy, Maintenance and Recovery.	A. Davister, A. Bourgot and P.A. Smith. *Port El Kantaoui, Tunisia, 1986. Ta/86/3. 40p.*

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b	A Short Description of the IMI Process for Cleaning of Wet Process Phosphoric Acid.	IMI (Tami). *Seville, Spain, 1972. Lte/72/4. 14p.*

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b	Super Acid - a New Approach to Granular Fertilizers.	J.M. Delong and P.W. Casperson. *Sandefjord, Norway, 1970. Lte/70/2. 25p.*
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b	A New Fluorine Recovery Process.	M.D. Sanders and W.C. Weber. *Helsinki, Finland, 1963. Lhe/63/10. 10p.*
c	The Continuous Recording of P_2O_5 Losses in Drains.	J.S.S. Reay. *Edinburgh, United Kingdom, 1965. Lee/65/16. 12p.*
d	Investigation of an Aerosol with Pilot Units Installed on Site.	G. Modig. *The Hague, the Netherlands, 1976. Ta/76/4. 13p*.
e	Fluorine Absorption and Indirect Condensation in Wet Process Phosphoric Acid Concentration.	M. Lahav and S. Arnon. *Orlando, Florida, USA, 1978. Ta/78/13. 6p.*
f	A Zero Discharge and Water Recycle System for Wet Process Phosphoric Acid Plants.	D.G. Mercer. *Orlando, Florida, USA, 1978. Ta/78/15. 12p*.
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h	Etude du Rapport F/SiO_2 en vue de Minimiser l'Emission du Fluor.	K. Lahmadi and A. Ben Attia. *Johannesburg, South Africa, 1996. 12p.*

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d	Environment-Friendly Production of Phosphoric Acid.	R.M. Vermeul, C.G.H. Van Ede, P.C.M. Mutsaers and N.W. Kolmeijer. *Amman, Jordan, 1994. 19p.*
e	Procédé Prometteur d'Elimination du Cadmium de l'Acide Phosphorique.	A. Kossir and M. Ghayor. *Johannesburg, South Africa, 1996. 6p.*

3. Nitrogen fertilizers

3.1 Urea and urea fertilizers

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b	Melt Oil Cooling Process for the Production of Urea-Based Compound Fertilizers.	A. Hatakeyama. *Seville, Spain, 1972. Lte/72/6. 14p.*
c	Process for Obtaining New Reaction Products of Phosphoric Acid, Urea and Ammonia, and their Applications in the Fertilizer Industry.	M. Gittenait. *Seville, Spain, 1972. Lte/72/8. 17p.*
d	Use of Urea in Complex Fertilizers: Results Obtained in Recent Years in the ERT Factories.	J. Olivares and J. Oliva. *Seville, Spain, 1972. Lte/72/ 9. 31p.*
e	Manufacture of IBDU and Compound Fertilizers Containing IBDU.	N. Yanai. *Seville, Spain, 1972. Lte/72/13. 17p.*
f	Low Investment and Optimization in the Production Costs of a Urea MAP-NPK Fertilizer Complex.	F.G. Membrillera, J.L. Thoral and F. Codina. *The Hague, the Netherlands, 1976. Ta/76/15. 18p*.
g	A Contribution to Energy Saving : a New Process for Urea Production.	G. Pagani. *Vienna, Austria, 1980. Ta/80/17. 9p.*
h	The Perlomatic Process.	C. Debayeux. *Paris, France, 1984. Ta/84/8. 8p.*
i	Energy Saving in Urea and Ammonium Nitrate Plants.	G. Brusasco, R. Monaldi, G. Pagani and M. Santini. *Paris, France, 1984. Ta/84/16. 22p.*
j	Montedison's IDR (Isobaric Double Recycle) Process - Process Improvements and Applications in the Urea Plant Retrofitting/ Revamping.	G. Brusasco and L. Mariani. *Edmonton, Canada, 1988. Ta/88/7. 13p.*
k	Project and Results for 500 Mtpd Urea Plant Revamp.	J.L. Hernandez and A. Rodriguez. *Venice, Italy,1990. 18p.*
l	Urea Technology Optimization.	V.M. Olevsky and M.E. Ivanov. *The Hague, the Netherlands, 1992. 11p.*
m	Reliability - a Must in Ammonia Production.	I. Dybkjaer. *The Hague, the Netherlands, 1992. 11p.*
n	A New Conception to Produce Urea-Superphosphate Fertilizers : the AZF USP Process.	L. Limousin, B. Neveu, J.P. Peudpiece, P. Achard and Y. Schwob. *Amman, Jordan, 1994. 15p.*
o	Revamp of Urea Plant to Improve Efficiency.	A. Karsono, E. Anwar and M. Djohan Safri. *Johannesburg, South Africa, 1996. 8p.*
p	Towards More Uniform Methylene-Urea, Slow-Release Fertilizer.	J. Luhtala and T. Koivumäki. *Johannesburg, South Africa, 1996. 9p.*
q	Stamicarbon's New Process Urea 2000plus.	K. Jonckers, J. Mennen, J. Meessen and W. Lemmen. *Johannesburg, South Africa, 1996. 10p.*
r	Upgradation of Ammonia-Urea Complex at IFFCO-Kalol for Sustained High Level Performance.	J. Ohri. *Johannesburg, South Africa, 1996. 11p.*
s	Corrosion Problems and Remedial Measures in Ammonia/Urea Fertilizer Plant.	M.S. Al-Rassi. *Johannesburg, South Africa, 1996. 13p.*

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a	Some Experiences on the Introduction of Urea Into Granular Mixed Fertilizers Based on Superphosphate.	D.A. Clur, R. Fogel, J.D. Mulder and D.J.M. O'sullivan. *Wiesbaden, Germany, 1961. Le/61/43. 9p.*
b	The Manufacture of Granular Compound Fertilizers Based on Urea as the Principal Source of Nitrogen.	J.D.C. Hemsley and F. Roig. *Seville, Spain, 1972. Lte/72/7. 26p*.
c	Production of Granular Urea by the TVA Falling Curtain-Evaporative Cooling Process.	R.S. Meline, A.R. Shirley Jr., L.M. Nunnelly and F.T. Carney. *Vienna, Austria, 1980. Ta/80/16. 10p*.
d	Granular Urea-Ammonium Sulphate - a New Fluid Bed Granulation Product.	V. Bizzotto. *Paris, France, 1984. Ta/84/7. 18p.*
e	Prilling or Granulation of Urea - some Comparative Criteria of Recently Developed Granulation Technologies and Improved Air-Prilling.	F. Kars. *Paris, France, 1984. Ta/84/10. 45p.*
f	Urea Granulation Plant at Ferrara.	G. Brusasco, A. Cavallaccio, M. Ognibeni and M. Santini. *Venice, Italy,1990. 13p.*
g	Products Quality Improvement on Urea Prills.	Y.A. Ibrahim. *The Hague, the Netherlands, 1992. 9p.*
h	Safco's Experience with Fluidized Bed Urea Granulation Process.	A.M. Al-Shamrani and K. Juma. *Amman, Jordan, 1994. 5p*.

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b	Process to Produce Large Granules of Ammonium Nitrate from Prills.	P. Chinal, C. Debayeux, H. Lacroix and J.B. Peudpiece. *Port El Kantaoui, Tunisia, 1986. Ta/86/8. 15p.*
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d	Manufacture of Ammonium Nitrate: the Use of a Pipe Reactor and of a Total Air Recycle System for Prilling Tower Pollution Control.	J.L. Lopez-Nino J.A. Zurbano, and L.M. Marzo. *Venice, Italy,1990. 8p*.
e	The New Fertilizer 'Calcourea'.	A. Crispoldi and A. Fogli. *Venice, Italy,1990. 8p.*
f	The Carnit Ammonium Nitrate Process - an Emphasis on Energy Efficiency and Environmental Compatibility.	J. Brandt and J. Renotte. *Amman, Jordan, 1994. 12p.*
g	Production of Ammonium Sulphate from Utility Boiler Waste Gas.	G.N. Brown. *Johannesburg, South Africa, 1996. 13p*.

4. Phosphate fertilizers

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b	Danish Sulphuric Acid and Superphosphate Works.	*Landskrona, Denmark, 1947. Le/56. 4p.*
c	On the Future of Phosphatic Fertilizers.	S. Nordengren. *Paris, France, 1951. Le/288. 7p.*
d	Calcined Phosphates.	G. Behnen. *Paris, France, 1951. Le/300. 4p.*
e	The Value of Hydrochloric Acid for the Fertilizer Industry.	A. Strauchen. *Wiesbaden, Germany, 1961. Le/61/44. 6p.*
f	Gas Scrubbing Systems in Fertilizer Industry?	P. Chinal, J.F. Priat and Ph. Segard. *Port El Kantaoui, Tunisia, 1986. Ta/86/19. 16p.*
g	Strategy for Saving Water in a Fertilizer Plant Situated in an Arid Region where Water Resources Are Scarce and Limited.	A. Benmansour and H. Essebaa. *Edmonton, Canada, 1988. Ta/88/20. 26p.*

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b	Continued Treatment of Superphosphate 'Montecatini-Bellinzoni' System.	B. Azria. *Landskrona, Denmark, 1947. Le/54. 6p.*
c	Theoretical Bases for Controlling and Regulating Superphosphate Production.	Cie De Saint-Gobain. *Milan, Italy, 25-26 September 1949. Le/151. 7p.*
d	A New Process for the Continuous Manufacture of Superphosphate.	Etablissements Kuhlmann. *Milan, Italy, 25-26 September 1949. Le/154. 4p.*
e	New Sulphuric Acid and Superphosphate Works at Harjavalta.	J. Lehmus. *Milan, Italy, 25-26 September 1949. Le/155. 4p.*
f	Possibilities of an Economic Production of Triple Superphosphate.	P. Guareschi. *Milan, Italy, 25-26 September 1949. Le/165. 4p.*
g	Notes on the Installation of Superphosphate and Sulphuric Acid Works in India, and Especially on those in Alwaye.	S. Nallaperumal. *Milan, Italy, 25-26 September 1949. Le/179. 7p.*
h	Superphosphate Production. The Influence of Various Factors on the Speed of Reaction and the Composition of the Product.	R.J. Nunn and T.P. Dee. *Cambridge, United Kingdom, 1953. Le/388. 9p.*
i	The Manufacture of Superphosphate in a Rotary Den.	J.T. Proter. *Cambridge, United Kingdom, 1953. Le/391. 3p.*
j	The Modification of Broadfield Acidulating Units in Egypt.	M. Chafik. *Cambridge, United Kingdom, 1953. Le/393. 2p.*
k	Study of the Evolution of the Superphosphate Industry in Greece.	A. Georgiou. *Cambridge, United Kingdom, 1953. Le/407. 3p.*
l	Superphosphate and its Alternatives. Factors Governing the Choice.	T.P. Dee. *Cambridge, United Kingdom, 1953. Le/411. 11p*.
m	The Theory of Superphosphate Stabilisation.	B. Meppen. *Aarhus, Denmark, 1955. Le/ 601. 17p.*

n	The Use of Surface Active Agents in the Preparation of Fertilizers.	R. Kaack. *Aarhus, Denmark, 1955. Le/602. 7p.*
o	Research on the Free Acid in Superphosphate.	A. Graire. *Aarhus, Denmark, 1955. Le/ 609. 15p.*
p	Contributions to the Bases of Control of Superphosphate Manufacture.	A.F. Sabry. *Aarhus, Denmark, 1955. Le/612. 5p.*
q	The Continuous Manufacture of Superphosphate in Rotary Dens - History and Recent Developments.	P. Moraillon. *Wiesbaden, Germany, 1961. Le/61/51. 5p.*
r	Contribution to the Improvement of Superphosphate Manufacturing Conditions by Means of the Use of Cationic Surfactants.	M. Boutault, Bruyneel and Kalinovski. *Edinburgh, United Kingdom, 1965. Lee/65/18. 12p.*
s	Direct Production of Granulated Superphosphates and PK-Compounds from Sulphuric Acid, Phosphoric Acid, Rock Phosphate and Potash.	A. Sinte Maartensdijk. *The Hague, the Netherlands, 1976. Ta/76/12. 14p.*
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u	Developments in TSP Production: Slurry Versus Powder Route Chinese Experience.	N.D. Ward and B.T. Crozier. *The Hague, the Netherlands, 1992. 11p.*

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b	Granulation of Superphosphate.	C. Heudier. *Cambridge, United Kingdom, 1953. Le/ 385. 6p.*
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d	Ammoniation of Superphosphate and Compounds Containing Superphosphate.	J. Angus. *Cambridge, United Kingdom, 1953. Le/401. 25p.*
e	Study of Granulation by Means of a Rotating Drier with Practical Application to the Designing of an Apparatus and to Production Control.	J.E. Leger. *Cambridge, United Kingdom, 1953. Le/425. 20p.*
f	The Granulation of Superphosphate Mixed Fertilizers.	W. Thiessenhusen. *Aarhus, Denmark, 1955. Le/605. 6p.*
g	Loss of Water Soluble Phosphates during Granulation of Superphosphates.	E.W. Schwehr. *Aarhus, Denmark, 1955. Le/611. 5p.*
h	Manufacture and Granulation of Enriched Superphosphate.	P. Moraillon. *Stockholm, Sweden, 1959. Le/59/57. 30p.*
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a	The Evolution of Fluorine in Superphosphate Production, and its Absorption.	A.L. Whynes and T.P. Dee. *Cambridge, United Kingdom, 1953. Le/389. 16p.*
b	Treatment and Disposal of Superphosphate Plant Effluents.	R. Donald. *Cambridge, United Kingdom, 1953. Le/392. 11p.*
c	Scrubbers for Superphosphate Den Gases. An Approach to a Rational Design Method.	K.A. Sherwin. *Cambridge, United Kingdom, 1953. Le/414. 21p.*

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e	The Evolution of Fluorine in the Course of Superphosphate Manufacture.	M. Tessier. *Madrid, Spain, 1957. Le/902. 6p.*
f	Measurement of Fluorine Evolution during Superphosphate Manufacture.	K.C. Scheel and J. Bochem. *Wiesbaden, Germany, 1961. Le/61/56. 14p*.
g	The Pilot Plant Recovery of Cryolite and Activated Silica in the Manufacture of Superphosphate.	T.K. Vahervuori. *Wiesbaden, Germany, 1961. Le/61/61. 6p.*
h	Rotating Disc Towers for SiF_4 Absorption.	G. Menin and G.B. Guarise. *Seville, Spain, 1972. Lte/72/19. 13p.*
i	Process for Recycling H_2SiF_6 Solutions Recovered by Gas Washing to the Den of Superphosphate.	R. Monaldi and G. Venturino. *The Hague, the Netherlands, 1976. Ta/76/1. 16p.*

5. NP and NPK fertilizers

5.1 Various processes and general aspects

a	Manufacture on a Conveyor Belt of NPK Compound Fertilizers Based on Superphosphate.	P. Dondin. *Stockholm, Sweden, 1959. Le/59/50. 6p.*
b	A New Process for the Direct Production of Concentrated Granular Complex Fertilizers.	M. Giorgini and W.C. Weber. *Stockholm, Sweden, 1959. Le/59/58. 12p.*
c	Comparison of the Economics of Three Processes for Manufacturing Compound Or Complex Fertilizers.	P. Moraillon. Helsinki, Finland, 1963. Lhe/63/4. 22p.
d	Study of the Constitution of Ternary Fertilizers Obtained by the Reaction of an Ammonium Sulphate Solution with Natural Calcium Phosphate in the Presence of a Potassium Salt.	A. Bechin. *Helsinki, Finland, 1963. Lhe/ 63/5. 22p.*
e	Potassium Dihydrogen Phosphate Manufacture.	W.H. Thompson and T.N. Somers. Sandefjord, Norway, 1970. Lte/70/16. 29p.
f	Development of New Fertilizer Products and Processes.	T.P. Hignett. *Seville, Spain, 1972. Lte/72/5. 28p.*
g	New Ways of Obtaining Potassium and Ammonium Potassium Polyphosphates.	J.L. Toral, E. Bibian and A. Gamero. Seville, Spain, 1972. Lte/72/ 17. 22p.
h	The Manufacture of Monopotassium Polyphosphates.	IMI (Tami). *Seville, Spain, 1972. Lte/72/18. 14p.*
i	Potassium Monophosphate Manufacture by Solvent Extraction.	E.D. Noguira, J.M. Regife and C. Gonzales. *Prague, Czechoslovakia, 1974. Pte/74/4. 16p.*
j	Direct Production of Granulated Superphosphates and PK-Compounds from Sulphuric Acid, Phosphoric Acid, Rock Phosphate and Potash.	A. Sinte Maartensdijk. *The Hague, the Netherlands, 1976. Ta/76/12. 14p.*
k	Economic and Technical Aspects in some Differential NPK Processes.	M. Autti, M. Loikkanen and P. Suppanen. *The Hague, the Netherlands, 1976. Ta/ 76/14. 19p*.
l	Low Investment and Optimization in the Production Costs of a Urea MAP-NPK Fertilizer Complex.	F.G. Membrillera, J.L. Thoral and F. Codina. *The Hague, the Netherlands, 1976. Ta/76/15. 18p.*
m	Innovations in Slurry Process Granulation Plants.	D.W. Leyshon and I.S. Mangat. *The Hague, the Netherlands, 1976. Ta/76/21. 33p.*
n	Significant Energy Savings in the Odda Process.	By M.H.G. Jennekens. *Paris, France, 1984. Ta/84/19. 41p.*
o	Start-Up in the USSR of Two of the World's Three Most Powerful NPK Granular Fertilizer Plants.	P. Chinal. *Paris, France, 1984. Ta/84/2. 22p.*
p	The Use of (N-P) Solid Raw Materials in the Production of Compound NPK Fertilizers.	N. Louizos. *Edmonton, Canada, 1988. Ta/88/4. 9p.*
q	Advantages of Complex Fertilizers in Logistics, Application and Environment.	J. Platz and K.H. Ulrich. *The Hague, the Netherlands, 1992. 25p*.
r	Evaluation of Production Flexibility and Costs by NPK Pilot Plant Experimentation.	F. Cocquio and G. Venturino. *The Hague, the Netherlands, 1992. 8p.*
s	Prospective Methods of Production of Slow-Release Capsulated Fertilizers with Regulable Nutrient Release.	V.M. Olevsky, M.K. Rustambekov and A.L. Taran. *Amman, Jordan, 1994. 17p.*

t	Use of Divers' Liquids in the Reduction of Heavy Metals during the Production of Phosphorus Fertilizers by Nitric Acid-Ammonia Process.	Z. Krawiec, B. Waligora and X. Nguyen. *Amman, Jordan, 1994. 3p.*

5.2 Ammoniation, MAP, DAP

a	The Incorporation of Ammonium Phosphate in Granular NPK Fertilizer.	F.J. Harris. *Stockholm, Sweden, 1959. Le/59/54. 8p.*
b	Mixed Phase Ammoniation for High-Grade Fertilizers with a Note on Analytical Methods.	F. Barzocchini and R. Monaldi. *Helsinki, Finland, 1963. Lhe/63/1. 30p.*
c	Experiments with Pre-Neutralisation in the Manufacture of Compound Fertilizers.	T.K. Vahervuori and P. Virtanen. *Helsinki, Finland, 1963. Lhe/ 63/2. 21p.*
d	The Use of a New Form of Monoammonium Phosphate in Place of Superphosphate as a Means of Attaining Higher Concentration in Granular NPK Fertilizers.	I.A. Brownlie and R. Graham. *Helsinki, Finland, 1963. Lhe/ 63/3. 26p.*
e	Production of Ammonium Phosphate in a Spray Tower.	L.G. Nilsson. *Edinburgh, United Kingdom, 1965. Lee/65/8. 13p.*
f	Pre-Neutralisation of Phosphoric Acid with Nitrogen Solution.	T.K. Vahervuori and P. Virtanen. *Edinburgh, United Kingdom, 1965. Lee/65/9. 23p.*
g	The Sair-R Process for the Manufacture of Compound Fertilizers Containing Ammonium Nitrate and Diammonium Phosphate.	J.W. Baynham. *Edinburgh, United Kingdom, 1965. Lee/65/12. 20p.*
h	Modified Diammonium Phosphate Production in a TVA Type Granulation Plant.	R.R. Heck. *Brusssels, Belgium, 1968. Lbe/68/5. 24p.*
i	Pilot-Plant Studies of an Anhydrous Malt Granulation Process for Ammonium Phosphate Based Fertilizers.	R.G. Lee, R.S. Meline and R.D. Young. *Sandefjord, Norway, 1970. Lte/70/5. 21p.*
j	Ammoniation Reactions of Wet-Process Phosphoric Acid.	J. Ando and T. Akiyama. *Seville, Spain, 1972. Lte/72/1. 23p.*
k	Intensive Ammoniation in the Preparation of Granulated Complex Fertilizers.	R. Loste, F. Prats and F. Pomares. *Seville, Spain, 1972. Lte/72/12. 20p.*
l	The Cros NPK Process. The Use of the Cheapest Raw Materials, and Better Raw Materials Recovery.	R. Loste, J.L. Toral and A. Cervera. *Prague, Czechoslovakia, 1974. Pte/74/3. 22p.*
m	Slurry Ammoniation in Complex Fertilizer Production. A New Type of High Efficiency Ammoniator.	I. Mini and R. Monaldi. The Hague, the Netherlands, 1976. Ta/76/11. 14p.
n	Pilot and Demonstration Scale Developments in Production of Ammonium Phosphate Based Fertilizers Using the Pipe and Pipe Cross Reactors.	B.R. Parker. *Orlando, Florida, USA, 1978. Ta/78/19. 28p.*
o	The Effect of Impurities on the Product Qualities of MAP.	J.A. Brownlie, E. Davidson, T.R. Dick and S.E. Martin. *Orlando, Florida, USA, 1978. Ta/78/20. 19p*.
p	The Use of MAP in Large Capacity Granulation Plants.	R.F. Barut and I. Kotlarevsky. *Orlando, Florida, USA, 1978. Ta/78/21. 11p.*
q	Effect of Impurities in Wet-Process Phosphoric Acids on DAP Grades.	F.P. Achorn, E.F. Dillard, A.W. Frazier and D.G. Salladay. *Vienna, Austria, 1980. Ta/80/11. 31p.*
r	Optimizing Use of Energy in the Production of Granular Ammonium Phosphate Fertilizer.	F.P. Achorn and D.G. Salladay. *Kallithea, Greece, 1982. Ta/82/ 5. 22p.*
s	Effects of Impurities on Production of Diammonium Phosphate.	M.M. Handley. *Paris, France, 1984.*

Ta/84/6. 22p.

t	Advanced Ammonia Phosphate Scrubbing with Minimum Water Discharge.	S.V. Houghtaling and V.J. Margiotti, Jr. *Amman, Jordan, 1994. 12p.*

5.3 Nitrophosphate processes (carbo-, sulpho-, phosphonitric)

a	A Remedy for the World Shortage of Sulphur.	M. Massenet. *Paris, France, 1951. Le/289. 11p.*
b	Notes on the Manufacture of Fertilizers by Nitric Solubilization of Phosphates.	Y. Martin. *Paris, France, 1951. Le/291. 7p.*
c	Notes on the Production of Superphosphates, Nitrates and Their Derivatives.	A. Constant. *Paris, France, 1951. Le/296. 6p.*
d	Progress in the Maintenance of Solubilization of Phosphoric Acid.	M. Massenet.*Cambridge, United Kingdom, 1953. Le/398. 3p.*
e	Reflections on The Evolution of Fertilizers - Compound Fertilizers.	Y. Martin. *Cambridge, United Kingdom, 1953. Le/412. 9p.*
f	Alternative Phosphate Fertilizers.	T.P. Dee. C*ambridge, United Kingdom, 1953. Le/418. 7p.*
g	Improvements in the Manufacture of Nitrophosphate Compound Fertilizers.	C. Heudier. *Aarhus, Denmark, 1955. Le/608. 2p.*
h	An Improved Method of Production for Complex Fertilizers.	Potasse et Engrais Chimiques. *Edinburgh, United Kingdom, 1965. Lee/65/10. 13p.*
i	The Manufacture of Compound Fertilizers by the Kampka-Nitro Process.	F.W. Brandt and H. Nees. *Edinburgh, United Kingdom, 1965. Lee/65/11. 13p.*
j	The Odda Process - Possibilites and Limitations.	O.H. Lie. *Brusssels, Belgium, 1968. Lbe/68/15. 19p*.
k	The Development of the Hoechst-Uhde Ammonium Nitrate Phosphate Process.	H. Banthien. *Brusssels, Belgium, 1968. Lbe/68/16. 16p.*
l	The 'Apex' Process for the Extraction of Phosphoric Acid for the Production of Phosphatic Fertilizers and Industrial Phosphates.	R. Amanrich, G. Cousserans and A. Mahe. *Sandefjord, Norway, 1970. Lte/70/8. 33p.*
m	Simultaneous Calcium and Chlorine Removal in NPK Fertilizer Production.	K.C. Knudsen. *Sandefjord, Norway, 1970. Lte/70/13. 22p.*
n	Operating Experience from the Modernised Norsk Hydro Odda NPK Process.	O. Haug and J.O. Pande. *Sandefjord, Norway, 1970. Lte/70/14. 25p.*
o	The Typpi Oy Solvent Extraction Process for Nitrophosphates.	N. Lounamaa, O. Numminen and L. Niinimaki. *Sandefjord, Norway, 1970. Lte/70/15. 23p.*
p	NPK Production by Ion Exchange: Operating Experience.	K.C. Knudsen. *Seville, Spain, 1972. Lte/72/11. 17p.*
q	New Experiences with the Kampka Nitro Process.	K. Tesche. *Seville, Spain, 1972. Lte/72/ 14. 21p.*
r	Process for the Manufacture of Complex Fertilizers by Nitric Attack of Phosphate Rock and Double Exchange with Potassium Sulphate.	I. Mini and R. Monaldi. *Seville, Spain, 1972. Lte/72/15. 23p.*
s	Czechoslovak Process of NP and NPK Fertilizer Production Based on Direct Cooled Continuous Crystallization.	R. Batrla. *Prague, Czechoslovakia, 1974. Pte/74/1. 18p.*

t	The Conversion of Calcium Nitrate Originating in a Nitrophosphate Plant with a View to Improving the Efficiency, as well as a Survey of the Possible Applications of the Products.	G. Lanchans and B. Bienok. *The Hague, the Netherlands, 1976. Ta/76/13. 19p.*
u	The BASF Odda NPK Process.	A.H. Durocher, L. Diehl and H.J. Eisen. *Paris, France, 1984. Ta/84/18. 26p.*
v	Significant Energy Savings in the Odda Process.	M.H.G. Jennekens and G.H.M. Calis. *Paris, France, 1984. Ta/84/19. 33p.*

5.4 Special techniques

5.4.1 Reactors

a	Pipe Reactor: an Innovation for Improvement of Granulation Plant Performances.	I. Mangat and J.M. Toral. *Orlando, Florida, USA, 1978. Ta/78/18. 15p*.
b	Pilot and Demonstration Scale Developments in Production of Ammonium Phosphate Based Fertilizers Using the Pipe and Pipe Cross Reactors.	B.R. Parker. *Orlando, Florida, USA, 1978. Ta/78/19. 28p.*
c	Savings on Energy in Granulation of Fertilizers by a New Method of Using Pipe Reactors.	P. Moraillon. *Kallithea, Greece, 1982. Ta/82/1. 22p.*
d	New Developments in the Dual Pipe Reactor Process.	P. Chinal and Y. Cotonea. *Paris, France, 1984. Ta/84/1. 22p.*
e	Powdered or Granular MAP and DAP via Pipe Reactor.	J.L. Lopez-Nino and L.M. Marzo. *Port El Kantaoui, Tunisia, 1986. Ta/86/9. 13p.*
f	SAEPA 1 Plant (Gabes) - History of a Continuous Improvement Increasing the Capacity from 1000t/D to 2000t/D.	M.L. Rahoui. *Port El Kantaoui, Tunisia, 1986. Ta/86/10. 14p.*
g	Effect of $NH_4NO_3.K_2SO_4$ Particle Size on Granulation Efficiency in Production of Npks Using the Pipe Reactor Process.	Wang Jin Ming. *Johannesburg, South Africa, 1996. 13p.*

5.4.2 Granulation

a	Production of Granular Compound Fertilizers. Notes on the Development and Operation of Granulation of Compound Fertilizers in Scottish Agricultural Industries Plants.	J. Angus and E.P. Hudson. *Landskrona, Denmark, 1947. Le/53. 15p.*
b	Granulation of Fertilizers in a Conical Drum.	N. Lagerholm. *Madrid, Spain, 1957. Le/908. 5p.*
c	Some Experiences in the Production of NPK Prilled Fertilizers at Barton-On-Humber, England.	T.A. Mitchel, B.H. Fothergill and W.J. Kelly. *Sandefjord, Norway, 1970. Lte/70/6. 16p*.
d	Agglomerate Granulation as an Equilibrium Process.	J.H. Van Der Leek. *The Hague, the Netherlands, 1976. Ta/76/6. 20p.*
e	Innovations in Slurry Process Granulation Plants.	D.W. Leyshon and I.S. Mangat. *The Hague, the Netherlands, 1976. Ta/76/21. 33p.*
f	Practical Aspects of Operation of a Granulation Plant for NPK Fertilizers of 1000 Tm/Day.	J. Olivares Del Valle, J.L. Lopez Nino Ans J. Castillas Revilla. *Vienna, Austria, 1980. Ta/80/13. 26p.*
g	The 'Adelaide Process' for the Granulation of Water Soluble Salts.	K.H. Walter. *Kallithea, Greece, 1982. Ta/82/13. 15p.*
h	Compacted Fertilizers.	A. Seixas. *Paris, France, 1984. Ta/84/11. 24p.*

i	The Use of a Pressure Neutralizer for Slurry Granulation.	D.M. Ivell and N.D. Ward. *Paris, France, 1984. Ta/84/3. 16p.*
j	Granulation of NPK Compound Fertilizers at the New Fertilizer Complex of Ina-Petrokemija, Yugoslavia.	J.A. Hallsworth, W.F. Fortescue and D. Fresl. *Paris, France, 1984. Ta/84/4. 19p.*
k	The Fluidized Drum Granulation Process (FDG) and its Various Applications.	T. Thuring and E. Vogel. *Port El Kantaoui, Tunisia, 1986. Ta/86/6. 23p.*
l	Production of NPK Fertilzers with a Spouted Bed Granulation-Dryer.	G. Brusaco, R. Monaldi, V. De Lucia and A. Barbera. *Port El Kantaoui, Tunisia, 1986. Ta/86/13. 22p.*
m	Recent Developments in the Pan Granulation Process.	P. Stokka. *Edmonton, Canada, 1988. Ta/88/5. 13p.*
n	High Quality Granular Ammonium Sulphate Production.	M. Fischbein and A.M. Brown. *Edmonton, Canada, 1988. Ta/88/6. 15p.*
o	Spherodizer Granulation of NPK by Nitric Attack: Process and Environmental Aspects.	G. Ciaccasassi, G. Gelli. *Venice, Italy,1990. 16p.*
p	Granulation of Hygroscopic Fertilizer ANP and CAN.	R.C. Desai and V.K. Karia. *The Hague, the Netherlands, 1992. 8p.*
q	Granulation and Fattening of Fertilizers Using the Kaltenbach-Thuring Fluid Drum Granulation (FDG) Technology.	E. Vogel. *The Hague, the Netherlands, 1992. 18p.*
r	Fluidized-Bed (FB) Dehydration on an Industrial Scale.	Y.Y. Kaganovich. *The Hague, the Netherlands, 1992. 8p.*
s	Sulphur Granulation with Kaltenbach-Thuering Fluid Drum Granulation (FDG) Process.	M. Besson. *Amman, Jordan, 1994. 12p.*
t	Effect of NH_4NO_3.K2SO_4 Particle Size on Granulation Efficiency in Production of Npks Using the Pipe Reactor Process.	Wang Jin Ming. *Johannesburg, South Africa, 1996. 13p.*

5.4.3 Miscellaneous

a	Grinding of Granulated Fertilizers in a Philips Coffee Mill.	G. Behnen. *Madrid, Spain, 1957. Le/936. 2p.*
b	Experiences on Cooling Fertilizers during Manufacture.	H. Schreiber. *Wiesbaden, Germany, 1961. Le/61/59. 4p.*
c	Safety in Rotary Dryer Operation.	G. Perbal. *The Hague, the Netherlands, 1976. Ta/76/2. 13p.*
d	Revamping of the Fertilizer Plant of the Societe Industrielle et Chimique du Nord de la Grece.	A. Constantinidis, J. Laine and D. Bellis. *Port El Kantaoui, Tunisia, 1986. Ta/86/12. 27p.*
e	The Stamicarbon Strip Venturi Scrubber - a New Concept of Dust and Fume Extraction (Patent Pending).	J.P. Nommensen. *Port El Kantaoui, Tunisia, October 1986. Ta/86/18. 16p.*
f	Nitrophosphate Plants - the Recycling Concept to Minimize Pollution of Air and Water.	L. Diehl. *Edmonton, Canada, 1988. Ta/88/12. 12p.*

5.5 Trace elements

a	The Incorporation of Trace Elements, Insecticides, Herbicides, in Compound Fertilizers.	E.W. Schwehr. *Stockholm, Sweden, 1959. Le/59/63. 9p.*

5.6 Decomposition

a	The Decomposition of Compound Fertilizers.	D.G. Huygen and G. Perbal. *Edinburgh, United Kingdom, 1965. Lee/65/13. 26p*.

5.7 Caking

a	The Measurement of some Storage Characteristics of Granular Fertilizers.	R.J. Nunn. *Wiesbaden, Germany, 1961. Le/61/42. 5p.*
b	The Adhesion of Powder Coating to Fertilizer Granules.	H. Pecht. *Wiesbaden, Germany, 1961. Le/61/57. 9p.*
c	Study of the Mechanism of Caking in some Nitrophosphate Fertilizers.	O. Kjoehl and A. Munthe-Kaas. *Sandefjord, Norway, 1970. Lte/70/19. 11p.*
d	Use of Amines against Caking of Fertilizers.	J. Breiss. *Sandefjord, Norway, 1970. Lte/ 70/20. 7p.*
e	A Method of Determining the Caking Tendency of a Fertilizer and the Effectiveness of Anti-Caking Agents.	P. Incastrone. *Sandefjord, Norway, 1970. Lte/ 70/21. 6p.*
f	Caking and Degradation of Granular Compound Fertilizers Containing Nitrates and Sulphates.	J. Ando. *Prague, Czechoslovakia, 1974. Pte/74/ 2. 16p*.
g	Hygroscopicity of Fertilizer Materials.	P. Hegner and L. Jaeger. *The Hague, the Netherlands, 1976. Ta/76/8. 16p.*

5.8 Liquids

a	Liquid Mixed Fertilizers: Technology and Economics.	T.P. Hignett. *Brusssels, Belgium, 1968. Lbe/68/7. 34p*.
b	Preparation of Solutions of Ammonium Polyphosphates for Liquid Fertilizers.	P.J. Gorrindo, E. Bibian and J.M. Sule. *Seville, Spain, 1972. Lte/72/ 16. 25p*.
c	Production of High-Polyphosphate Liquid Fertilizer by the Pipe Reactor Process.	S. Meline. *Prague, Czechoslovakia, 1974. Pte/74/5. 23p.*
d	Liquid Fertilizer Production: Structure of a Distribution Network.	F. Fraiteur. *Prague, Czechoslovakia, 1974. Pte/74/6. 15p*.
e	Production and Distribution of Liquid Fertilizers.	G. Morandi. *Prague, Czechoslovakia, 1974. Pte/74/7. 21p.*
f	Experimentation on the Use of Urea-Ammonium Sulphate (UAS) Liquid Fertilizers in Kuwait.	M.F. Abd El-Hameed. *Paris, France, 1984. Ta/84/9. 9p.*
g	A New Process for the Production of Concentrated Ammonium Nitrate Solutions.	P. Chinal, G. Cousserans, J.P. Peupiece and J.F. Priat. *Edmonton, Canada, 1988. Ta/88/9. 13p.*
h	Specialized Liquid Complex Fertilizers in Lithuania.	A.M. Sviklas. *The Hague, the Netherlands, 1992. 8p.*
i	Tailor Made Liquid NPK Fertilizers - a Unique Production, Distribution and Application Method.	M. Hochberg and Y. Nitzani. *Johannesburg, South Africa, 1996. 5p*.

6. Packing, handling, transport, distribution

6.1 General

a	A Modern Solution to the Problem of Storing, Conditioning, Packing and Loading Superphosphate.	P. Cambau. *Aarhus, Denmark, 1955. Le/607. 14p.*
b	Arrangements to Increase Seasonal Dispatch Capacity Specially for Fork-Trucks.	A. Wentzel. *Stockholm, Sweden, 1959. Le/59/64. 6p.*
c	The Port Handling of Fertilizers and Fertilizer Raw Materials in Sacks and Bulk.	J.H. Bost. *Sandefjord, Norway, 1970. Lte/70/17. 22p.*
d	The International Transport Codes and their Importance to the Fertilizer Manufacturer.	P. Rolfsen. *Seville, Spain, 1972. Lte/72/20. 13p*.
e	Comparison Between Bulk and Pallet Storage in a New Straight and Compound Fertilizer Plant.	M. Sanchez-Herrero and P. Ayerbe Mora. *Prague, Czechoslovakia, 1974. Pte/74/9. 22p.*
f	Some Developments in the Storage, Handling and Distribution of Compound Fertilizers.	J.W. Baynham and A.M. Mcleod. *The Hague, the Netherlands, 1976. Ta/76/10. 19p.*

6.2 Bags / Bulk

a	L'Emballage des Engrais Phosphates.	A.T. Brook. *Cambridge, United Kingdom, 1953. Le/ 404. 23p.*
b	Practical Trials on Superphosphate Packing in Egypt.	M. Shafik. *Aarhus, Denmark, 1955. Le/614. 3p.*
c	Routine Laboratory Control of Paper Bags.	S. Hellestam and E. Sundston. *Madrid, Spain, 1957. Le/906. 4p.*
d	Fertilizers Packaging and Weighing with Particular Reference to Weighing.	J. Angus. *Madrid, Spain, 1957. Le/909. 8p.*
e	Automatic Weighing of Fertilzers.	M. Moyrand. *Madrid, Spain, 1957. Le/900. 3p.*
f	A Method of Distributing Fertilizers in Bulk.	E. E. Bragg. *Wiesbaden, Germany, 1961. Le/61/49. 4p.*
g	The Development and Use of Plastic Sacks for Fertilizers.	E.W. Schwehr. *Helsinki, Finland, 1963. Lhe/63/12. 28p.*
h	Problems in Fertilizer Bagging.	J.J. Porter. *Brusssels, Belgium, 1968. Lbe/68/11. 15p.*
i	Some Recent Developments in Fertilizer Packaging and Subsequent Handling.	W. Miller. *Brusssels, Belgium, 1968. Lbe/68/12. 23p.*
j	High Speed Bagging and Handling.	R. Dean. *Brusssels, Belgium, 1968. Lbe/68/13. 13p*.
k	Development of an Automatic Fertilizer Packing, Handling and Distribution System.	C. Gowran and H.J. Browne. *Prague, Czechoslovakia, 1974. Pte/74/ 8. 23p.*
l	Stretch Film.	P. Vigre. *Prague, Czechoslovakia, 1974. Pte/74/10. 10p.*
m	Product Quality Requirements in Bulk Shipment of Fertilizers.	O. Kjohl. *The Hague, the Netherlands, 1976. Ta/76/9. 21p.*

7. Disposal of by-products

7.1 Fluorine

a	The Recovery of Sulphuric Acid in the Manufacture of Sodium Fluosilicate by Using Sodium Sulphate.	M. Shafik and A. Sabry. *Wiesbaden, Germany, 1961. Le/61/45. 7p.*
b	Fluoride of Aluminium as a By-Product of Superphosphate Manufacture.	F. Weinrotter. *Helsinki, Finland, 1963. Lhe/63/11. 17p.*
c	Fluorine Recovery in the Phosphatic Fertilizer Industry.	P. Pothen and K.V. Nair. *Brusssels, Belgium, 1968. Lbe/68/8. 27p.*
d	The Production of Aluminium Fluoride from Waste Gases of Phosphoric Acid Plants.	R. Richter. *Prague, Czechoslovakia, 1974. Pte/74/17. 13p.*
e	Sodium Silicate and Calcium Fluoride from Sodium Fluosilicate.	A.F. Sabry. *Orlando, Florida, USA, 1978. Ta/78/14. 6p.*

7.2 Gypse

a	The Utilisation of By-Product Gypsum by High-Temperature Processes.	R.F. Knight. *Aarhus, Denmark, 1955. Le/603. 16p.*
b	Disposal of Gypsum.	N.D. Gopinath. *Helsinki, Finland, 1963. Lhe/63/18. 27p.*
c	Ammonium Sulphate from Phosphogypsum.	E. Sacher. *Brusssels, Belgium, 1968. Lbe/68/17. 13p.*
d	Utilization of Waste Gypsum from the Chemical Industry.	M. Haerter. *Brussels, Belgium, 1968. Lbe/68/4. 14p.*
e	Phospho-Gypsum Beneficiation Process.	T. Yamaguchi. *Seville, Spain, 1972. Lte/72/ 3. 10p.*
f	Processing in Accordance with the Giulini Method of Synthetic Gypsum from Phosphoric Acid Production to High-Grade Construction Materials.	H.J. Foerster. *Prague, Czechoslovakia, 1974. Pte/74/20. 15p.*
g	Production of Pure Calcium Sulphate Hemihydrate.	A. Kurandt. *Prague, Czechoslovakia, 1974. Pte/74/21. 21p.*
h	The Use of By-Product for Making SO_2 Gas and Portland Cement.	W. Binder. *Prague, Czechoslovakia, 1974. Pte/74/18. 18p.*
i	Valorisation of Phosphogypsum - the Charbonnages de France Chimie - Air Industrie Process.	B. Neveu. *The Hague, the Netherlands, 1976. Ta/76/3. 16 P*.
j	Production of Syntheric Fluor-Spar from Waste Fluosilicilic Acid.	K, Hellberg, F. Wollstein and S. Schneider. *The Hague, the Netherlands, 1976. Ta/ 76/22. 4p.*
k	Use of a Low Grade Phosphate Rock for Phosphoric Acid Manufacture Taking Into Consideration the Utilisation of By-Product Gypsum.	A.J. Kabil, E. Birox and R. Wiesbock. *Vienna, Austria, 1980. Ta/80/6. 11p.*
l	The Use of Phosphoric Acid Gypsum in the Building Industry.	H.F. Kurandt. *Vienna, Austria, 1980. Ta/80/9. 9p.*
m	Prayon Industrial Experience of Manufacturing Merchant Grade Phosphogypsum.	A. Bourgot, P.A. Smith. *Edmonton, Canada, 1988. Ta/88/16. 23p.*

7.3 Uranium

a	The IMC/Prayon Uranium Recovery Process.	F.T. Nielsson and A. Dubreucq. *Vienna, Austria, 1980. Ta/80/7. 35p*.
b	Uranium from Phosphoric Acid - the Earth Sciences Process.	I.S. Mangat and J.H. Viellenave. *Vienna, Austria, 1980. Ta/80/9. 22p.*
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Appendix 1

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Technical Conferences

1947 - 1996

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