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DUST CONTROL IN NPK PRODUCTION

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1. INTRODUCTION

The formation, recovery and handling of dust are some of the most serious problems faced by the fertilizer industry. Dust control, recovery and collection have become increasingly important in recent years. This is because environmental protection and stiffer requirements for occupational health -in addition to the reduction of losses- have become more important in all countries. Securing manpower also requires creation of the best working conditions possible, and dust-free productive facilities play a major role.

Dust originates mainly from the finest portion of powder raw materials and from attrition and crushing of the fertilizer granules. Fine dust formed in the manner mentioned above is carried by air currents.

Dust generally forms in the following stages of production at a NPK fertilizer plant :

- handling of solid raw materials
- granulation
- drying
- screening
- crushing
- conveying
- cooling
- coating system

Dust quantities may vary for different fertilizer grades, depending on the compound analysis and on the physical properties of the granule. These differences are due to the fertilizer grade, the raw material used and the production process.

By choosing the process and dust collection equipment most suitable for each fertilizer grade, we can reduce dust formation and also control the dust that is formed.

We will discuss below the influence of the fertilizer grade and the raw material on the dust quantities and the effect of a few process variables and types of equipment on it. We will also explain the solutions which Kemira Oy has applied at its newest complex fertilizer plants for the recovery and treatment of dust and for achieving dust-free production facilities.

2. THE EFFECT OF THE FERTILIZER FORMULATION AND PRODUCTION PROCESSES ON DUST FORMATION

A. Production processes

Kemira Oy produces several different fertilizer grades at its plants, e.g. 15-20-15, 15-25-10, 10-20-20, 7-24-14, 20-10-10 and 15-15-15. The amount of dust handled hereby varies today between 30 - 300 kg/product ton.

Grade 15-20-15 accounts for more of our production than any other grade. It is produced at nearly all our plants. Several different raw materials and processes are used. This grade has once caused dust problems at our Kokkola plant, where a process based on the use of dilute sulphuric acid (scrubber acid) is employed (Process 1) (1). Dust difficulties have not arisen in conjunction with the other grades such as 10-20-20 + Mg + B and 7-24-14 + Mg + Mn + B. Dust formation in process 1 with 15-20-15 is compared with the production of the same grade by means of an ammonium phosphate-based process at Uusikaupunki (Process 2) and a phospho-nitric process at Siilinjärvi (Process 3)

Table 1

Process 1 Kokkola	Process 2 Uusikaupunki	Process 3 Siilinjärvi
Dilute sulphuric acid approx. 30 % H_2SO_4	Ammonia	Ammonia
N-solution 24 % NH_3 60 % NH_4NO_3 15,8 % H_2O	Nitric acid 60 % HNO_3	Nitric acid 60 % HNO_3
MAP	Phosphoric acid 48 % P_2O_5	Kola-rock 39 % P_2O_5
KCl	Phosphoric acid slurry with gypsum 21 % P_2O_5	Phosphoric acid 43 % P_2O_5
		Sulphuric acid 93 % H_2SO_4
	KCl	KCl

The raw material for different processes used in the production of 15-20-15 is shown in Table I. The processes can be described shortly as follows :

Process I — A salt solution, obtained by neutralizing dilute sulphuric acid with N-solution, is concentrated in an evaporator. Solid monoammoniumphosphate, part of the N-solution and the potassium salt are dissolved in the solution obtained. The slurry formed is fed into the granulation unit. Granulation can be performed with either a blanger or a granulation drum. A conventional drying drum and cooling drum are then used.

Process 2 — Nitric acid and phosphoric acid are neutralized with ammonia in reactors and the slurry obtained is fed into the blunger. Dry potassium salt enters the blunger together with the recycle. Conventional drying drums and cooling drums are used.

Process 3 — A slurry composed of all the raw materials is produced in the digester and the neutralization reactors and sprayed into the spherodizers. Granulation and drying occur in the spherodizer and drying takes place immediately after granulation. A cooling drum is used.

B. Influence of compound analysis and physical properties on dust formation

The chemical and physical properties of grade 15-20-15 produced with different processes and the dust quantities formed in drying and cooling are shown in Table 2. Chemical analysis reveals rather clear differences in nitrate, sulphate and calcium contents.

It is shown in compound analysis by X-ray diffraction that among other things grade 15-20-15 produced with process 1 only contains the mixed salt $(NH_4,K)_2SO_4$. This salt has been found to get enriched in dust formed in dryer. The existence of this salt depends on the $SO_4:NO_3$ ratio.

Physical properties indicate the strength of the granules. The attrition percentages refers to attrition occurring under standard conditions, during the test. Pore volume indicates the quantity of pores in the granule. Of these figures, attrition in particular indicates the tendency to form dust under conditions similar to those present in drying and cooling.

TABLE 2

	15 - 20 - 15		
	Process 1	Process 2	Process 3
Chemical analysis %			
- NH_4-N	12,0	10,4	9,3
- NO_3-N	3,0	4,6	5,7
- P_2O_5			
total	20,0	20,0	20,0
water soluble	18,0	16,2	14,7
- K_2O	15,0	15,0	15,0
- SO_4	16,3	8,2	3,9
- Ca	0,5	2,8	3,5
Compound analysis by X-ray diffraction %			
- $NH_4H_2PO_4$	25	25	20
- $(NH_4)_2HPO_4$	3	3	3
- NH_4Cl	14	15	17
- KNO_3	3	6	9
- KCl	4	3	
- $(NH_4,K)_2SO_4$ (65:35)	12		
- $(NH_4,K)_4SO_4(NO_3)_2$ (50:50)	32	22	8
- $NH_4NO_3 \times 2KNO_3$		16	26
- $CaHPO_4$			3
- Precipitated apatite		9	12
- Precipitated iron phosphate	6		
Physical properties of granule			
- force to break granule, kp	8-10	12	12
- attrition %	1-7.	0,7-1,5	0,2
- pore volume ml/g	0,025-0,08	0,02	0,008
Quantity of dust t/h			
- after drying drum	5-30	0,5-1	0,5-0,8
- after cooling drum	1-1,5	0,1	0,02
Capacity t/h	30	22	30

The table indicates that in the production of grade 15-20-15 by process 1 sometimes more than 20 times as much dust has been formed as by the other processes. This formation of dust clearly corresponds to the physical properties of granules, as table 2 shows. In conjunction with grades 10-20-20 + Mg + B and 7-24-14+ Mn + B produced with process 1, the dust quantities are about the same as those for processes 2 and 3

C. The granulation mechanism

Since grade 15-20-15 has caused dust difficulties when process 1 is used, it has been the subject of more research. Particle size distributions for dust collected by cyclones after drying when grade 15-20-15 is produced with processes 1,2 or 3 are shown in appendix 1. Small particle size, in addition to high dust quantity, are problems that occur when process 1 is used. Microscope studies indicate that the dust formed in the production of 15-20-15 with processes 2 and 3 is composed of relatively large fragments of granules. In contrast, dust produced with process 1 is composed to a large extent of single crystals in the 50-100 μ range.

Chemical analysis of the different sieve fractions for samples taken from various process stages (appendix 2) indicates that SO_4 is greatly enriched between the 200-325 mesh sieves in process 1. This corresponds to a particle size of 43-74 μ. A corresponding enrichment of SO_4 does not occur in the dust of the 15-20-15 grade produced by other methods. According to X-ray diffraction studies, SO_4 appears mainly as a mixed salt $(NH_4,K)_2SO_4$ in the sieve fractions in question.

According to the element distribution pattern obtained by X-ray microanalysis of the granules, the K and S distributions are completely identical and there is a clear gap (appendix 3) at the corresponding areas in the P and Cl distributions. This is a $(NH_4, K)_2SO_4$ crystal, whose size can be estimated at 40-100 μ on the basis of the element distribution pattern. This corresponds to the sieve fractions with maximum SO_4 in the dust. It is thus obvious that large crystals of this type have formed in the stage preceding the granulation. Enrichment of SO_4 into dust shows that the sticking tendency of these crystals is relatively low in the granulation stage.

Studies of hot salt solution after the evaporation stage under the microscope show that the solution contains crystals in the 40-100 μ range. Chemical analysis of these crystals shows that they are mainly composed of $(NH_4)_2 SO_4$. Thus it is obvious that $(NH_4)_2SO_4$ the solubility of which is quite low and which crystallizes in the evaporation stage, is the initial reason for the tendency to form dust. Microphotographs (in appendix 4) taken of a thin section of the granule show surfaces, formed in various recycles. Inside these surfaces there is a dense layer of small crystals and a loosely structured layer of large crystals on the outside of these surfaces.

The pictures permit us to trace the granulation mechanism in the following manner. When the slurry composed of solution and crystals comes into contact with the porous granules of the recycle, the solution tends to penetrate into the pores and the solid substance composed primarily of $(NH_4,K)_2SO_4$ crystals remains on the surface of the recycle granule in the form of a loosely structured filtercake-like layer. As the water evaporates from the dissolved portion in the drying drum, the salts, deposited as small crystals, act as a binding agent, cementing the penetrated portion to a dense layer. The amount of this binding agent in the coarse crystals in the so-called filter cake layer decreases due to penetration and a weak point remains. This kind of granule breaks on mechanical handling at the weak point. Thus both dense layers and loose, porous layers appear in the granule. The loose layers can be shown by permitting the granules to absorb a dye solution. The split granule is then photographed, revealing the loose layer, which is now dyed. If the granule is dense, e.g. in spherodizer granulation products, penetration of the dye solution into the granule does not occur. The quantity of sulphate in the slurries of processes 2 and 3 is so small that $(NH_4)_2SO_4$ does not crystallize in the slurry to any significant extent. Furthermore, the solution does not penetrate into the pores in process 3, since granulation and drying occur nearly simultaneously.

D. The effect of chemical factors on dust formation

Impurities in phosphoric acid

Phosphoric acid impurities entering process 1 along with the MAP have a significant effect on the granule properties and dust formation. The amount and the nature of the impurities depend on the process used in the production of phosphoric acid.

The granulation and dust problems are more pronounced when MAP is produced from so-called hemi-dihydrate acid. In this case the dust formed in drying is 15-30 t/h but only 5-10 t/h when MAP produced from normal dihydrate acid is used. In the former case, dust is fine compared to processes 2 and 3 as shown in appendix 1. In the latter case the particle size range is coarser approaching particle size distribution curve for process 2. The attrition values range from 5-7 % to 1-3 % and pore volumes from 0,05 - 0,08 ml/g to 0,025 - 0,04 ml/g respectively illustrating dense and mechanically resistant granules on the dihydrate route basis compared to porous and brittle granules on the hemi-dihydrate route basis.

According to chemical analysis the Al-content of the MAP is about four times higher on dihydrate route basis, in agreement with results presented previously at ISMA meetings (2,3), X-ray diffraction studies show well crystallized water insoluble material in the "hemi-di-MAP" and nearly completely amorphic structure in "dihydrate MAP" illustrating the role of gel-like substance in improving the granulation properties of 15-20-15 grade made by process 1.

On the basis of the granulation mechanism presented above, the effect of the gel-like substance on the granulating properties can be understood so that it delays the absorption of the dissolved part of the slurry by the pores and thus the binding agent cements more effectively the otherwise brittle $(NH_4,K)_2SO_4$ layer. This reduces the average pore volume of the granule and the surface remains sticky after the slurry comes into contact with the recycle granule. The stickiness of the granule surface helps the fine material to adhere and increases granule size rapidly.

Excessive stickiness of the granular substance is a draw-back when "dihydrate-MAP" is used. Therefore the amount of recycle must be increased in comparison with the use of "hemi-di-MAP".

The difficulties caused by "hemi-di-MAP" were the opposite. As the dissolved part of the slurry was absorbed by the recycle, which had a relatively high pore volume, the surface of the granules remained dry. The dust returned to the granulator adhered only loosely to this kind of surface or passed through the granulator and overloaded the dust collection equipment, causing a high "dust circulation load".

The effect of nitrate and $MgSO_4$

The formulation used on a production scale in process 1 is based on the raw materials MAP, potassium salt, diluted H_2SO_4 and N-solution. This leads to a NO_3-N content of approximately 3 %. The addition of nitrates to the formulation calls for replacement of part of the H_2SO_4 with nitric acid. Grade 15-20-15 containing 3.7 % NO_3-N is made in pilot plant in this way. The formulation is filled with $MgSO_4$, in which case the Mg content of the product is 0.8 %. The findings revealed the following :

- The mechanical resistance of the granules increased considerably. According to a test, attrition decreases substantially, showing the anticipated decrease in the dust quantities on a production scale.

- The formation of granules speeds up and the stickiness disappears immediately after formation of the granule. As a result, the recycle ratio drops about 50 % in comparison with the normal formulation. Similar results appear in literature concerning the effect of KNO_3 on granulation properties (4).

The effect of the surface active agent

Surface active agents increase dust quantity and have a detrimental effect on granule properties. On the basis of the granulation mechanism described above, it is clear that when surface tension decreases, the dissolved part of the slurry penetrates further into the recycle granule and the amount of binding agent in the "filter cake layer" decreases. Thus the porosity of the granules increases while the stickiness of the surface decreases.

3. THE EFFECT OF THE PROCESS EQUIPMENT ON DUST FORMATION

A. Granulation

Granulation is one of the most important stages of the NPK process in dust formation. Both the blunger and the granulation drum are used in process 1 and grade 15-20-15 is granulated with both of them. Research findings indicate that the granulation drum is better suited to this formulation than the blunger. The dust quantity decreases about 30 % in comparison with the blunger when a drum granulator is used. The granules are also somewhat harder and rounder and the granulation efficiency is better. Using the drum granulator requires experience, however, because due to the above mentioned granulation mechanism, retention time in the granulation zone has an effect on the formation of dust. When the retention time is long, large amounts of dust appear and granulation is not very effective. An excessively short retention time causes oversize and difficulties with the crushers (appendix 5). With dust formation in mind, the optimum retention time depends on the chemical-physical properties of the raw materials. Thus the optimum retention time in the granulation zone when using "dihydrate-MAP" is twice that when using "hemi-di-MAP".

The proved superiority of the drum granulator cannot be applied very widely, for the fertilizer formulation has a considerable significance. The granulation drum usually provides better possibility to regulate granulation conditions by changing the rotation speed, the point at which the slurry is fed into the drum and retention in the granulator so that they best fulfil the requirements of the fertilizer formulation.

The blunger used in process 2 and the spherodizer used in process 3 have produced very hard granules which yield little dust. The formulation and slurry used in these processes are well suited for the granulation method used. In both cases the slurry is a salt melt in which there are few crystals. Granulation involves the "onion skin" mechanism in process 3. Process 3 does not, however, suit fertilizer grades with a high potassium content, for potassium salt does not dissolve in the slurry and is separated from the slurry in spraying.

B. Drying and cooling

The largest quantities of dust are normally formed in drying. According to our experience, drying equipment does not have the same significance for dust quantities as the raw materials and the fertilizer grade. In drying more dust is separated from weak granules than from strong ones. Table 2 offers evidence of this. It can be seen from this table that dust quantities in general are related to the hardness values of the granule. The same applies to cooling. The hardest granules have been obtained with process 3 and the attrition and hardness values are a further proof of this. And although the rotation speed and speed of the cooling gas in the cooling drum in this process are higher than in other methods, less dust is released from the granules.

C. Crushing and screening

Crushers frequently create a lot of dust at fertilizer plants. Hammer mills and chain mills, in which the rotation speed is high and oversize is ground fine, often cause great difficulties with dust. This is due to the fantype effect of these crushers. Rolling crushers cut down the dust quantities and are easier to connect with the general dust collection system. This is because they require a smaller amount of suction air when dust is collected to general dust collection system.

The selection of a crusher is not simple. In many cases, depending on the fertilizer formulation, rolling crushers cannot be used, due to the adhesion of the fertilizer. In some processes the aim is to make the oversize very fine, while in others it is enough to make it slightly smaller than the commercial size. These are usually the primary considerations in choosing a crusher. Dust is a secondary matter.

Screen also produce a certain amount of dust , but by using lids on the screens and a sufficiently large amount of dust removal air from the hopper below the screens, dust can be collected effectively. Kemira Oy has experimented successfully separating screens and crushers from the rest of the plant with simple walls.In this way the spread of dust and also noise from the crushers and the electromagnetic screens to the rest of the plant has been prevented. Loading of the plant bins with solid raw materials has been separated from the rest of the plant in a similar manner. Solid raw materials such as potassium salt, phosphate and magnesium sulphate are usually brought into the plant on conveyor belts and produce dust above the bins. The spread of dust in the plant has been prevented in the manner presented above. Solutions of this type should be made already in the planning stage of the plant. When they are made later, it has proved to be much more difficult and more expensive.

D. Conveyors

Dust is formed in transporting fertilizers and especially where they are dropped from conveying belts. Conveying belts are generally covered on both sides where dropping occurs ; a dust collection hood is also built at the same place and connected to the general dust collection system. Screw conveyors are most often used by Kemira Oy for dust collection. They are made entirely of steel or are fitted with a rubber shell. Conveyors fitted with a rubber shell have proved effective, particularly in handling moist dust. Very fine solids, such as the talc used in coating and trace elements used in the process are transported pneumatically and it appears that this mode of transport will spread throughout the fertilizer industry in the near future. The method is dust-free - this is its primary advantage. When small quantities have to be transported the purchase price is also competitive with other types of equipment.

4. COLLECTION, RECOVERY AND RETURN OF DUST TO THE PROCESS

Even when a suitable process for the production of complex fertilizers and raw materials for a particular fertilizer grade are chosen, dust is still produced at some stages, as mentioned above. The collection, recovery and return of this dust to the process is much the same for all fertilizer processes and finally the extent to which losses are reduced, what the dust effluents are, and the extent to which we can make our plant dust-free, depend on these measures.

A. Dry collection of dust

Dust from fertilizer plants in general follows gas currents and thus the largest quantities of dust are in the drying and cooling gases and in the general dust collection system, where dust is collected with suction air. To the extent possible, Kemira Oy has attempted to collect the dust and return it to the process in dry form, without using water. This makes it easier to control the plant water balance, for the large dust quantity requires a lot of water ; there is already a likelihood of excessive amounts of nutrient bearing water at fertilizer plants. Returning water to the process always causes difficulties and expense, and due to nutrient content, the water cannot be released into the environment.

Temperature, the moisture content of the gas and dust and the possible hygroscopic nature of the dust generally make dry collection difficult. These properties depend on the fertilizer grade and the process, and make demands on the dust collection equipment chosen.

Cyclones.

Dust is usually collected from drying gases with high-efficiency batteries of cyclones. A cyclone battery comprises cyclones with a capacity of 10.000 to 20.000 cu.m. of gas an hour. Usually 92-98 % efficiency is achieved, depending of course on the size of the dust particle. The pressure drop is 100-110 mm WG. The cyclones we use are insulated and fitted with air locks. They are very reliable and do not become plugged, since they are fitted with cleaning equipment.

Bag filters

Along with cyclones, we have also used bag filters to collect dust from gases in the drying drum. The bag filter uses a reverse air jet for cleaning; the tubular material is polyester fibre. Dust is collected very thoroughly by the bag filters, but the filter does require continual inspection and disturbances in the dryer furnace are reflected immediately in the bag filter, causing trouble there. The most common difficulties have been rapid soiling of the tubes, which causes a pressure drop of 200-250 mm WG, loosening of the tubes and moisture difficulties. The tubes need daily inspection and should be washed at 6 month intervals. In general, the bag filter has done a satisfactory job of collecting dust from the drying gases, although we prefer efficient cyclones in this case, due to their reliability and much lower operating costs.

We have used bag filters with a great deal of success in collecting dust from gases in the cooling drum. Bag filters employing reverse air jet cleaning or shaking cleaning have functioned perfectly. The pressure drop has been approximately 100 mm WG, and the dust content in the gas after the use of the bag filter has been 5-20 mg/cu.m. with a collection efficiency of 99,5 + %. Cooling gases can be conducted directly to the stack after bag filtration, or they can be returned to the process for use as dilution air in the drying drum furnace.

The following equipment, in which dust formation occurs, has been connected to the general dust collection system with air ducts :

- crushers
- screens
- conveyors and dropping points
- coating system
- scales

Dust is collected from the gases with the bag filter, just as from the cooling gases and with equal success and collection efficiency.

The bag filter is a very good dust collection device for purifying cooling gases and gases from the general dust collection system at fertilizer plants. High collection efficiency, dry collection of dust and a reasonable purchase price are some of the advantages of bag filters. The following are the disadvantages :

- requires a large amount of space
- does not work with hygroscopic dust
- needs care to avoid dew point
- rather high maintenance costs

Regardless of how well a fertilizer plant is maintained and the quality of the equipment used, local leaks do occur, or fertilizer granules and dust get into the factory in conjunction with repairs, and these have to be cleaned up. We have installed central cleaning systems at our fertilizer plants in which dust and granules are sucked out through a stationary pipe network, by means of a vacuum cleaner type device. The dust and fertilizer granules collected are returned to the process, as is other dust.

B. The return of dust to the process

Dust which is recovered and collected dry is transported by screw conveyors, either to the granulator or the reactor where it is combined with the slurry depending on the process.

It is important not to transport dust on the recycle conveying belts, because this causes dust difficulties on the belt and overloads the general dust collection system. Dust is transported separately with its own screw conveyors. When dust quantities are not too large and the process permits it, they can be conducted to the reactor and combined with the slurry. In this case the dust does not form brittle dust lumps, which break down in drying and become dust once again. In process 3 at Kemira Oy, dust is returned to the reactor. In other processes dust is transported to the granulator.

C. Wet collection of dust

Gas scrubbers

Wet collection is used when thorough dry collection is not possible or not profitable for one reason or another. The efficiency of the cyclones is not sufficient for the fertilizer dust and the drying gases are conducted to the scrubbers after the cyclones. Kemira Oy has used several different scrubber types including impingement scrubbers, sieve trays scrubbers and floating bed scrubbers. For scrubbing fine fertilizer dust the three types differ very little. There are more differences with regard to scrubbing of gases. Sieve trace scrubbers and floating bed scrubbers are better than impingement scrubbers in this respect. Reliability, the possibility to use a washing liquid with a high solid content and low pressure loss are some of the advantages of impingement scrubbers. Kemira Oy has installed floating bed scrubbers in its newest plants, where both dust and gases are scrubbed.

Under optimum conditions, exhaust gases from fertilizer plants contain about 30 mg/cu.m. of dust, but disturbances make the constant average around 80 mg/cu.m. At Kemira Oy NPK-plants dust effluents have been recently 0.5-1.8 kg/product ton.

5. SUMMARY

This paper has dealt with dust formed in the production of fertilizers and the experience accumulated by Kemira Oy on the control, recovery and collection of dust. Fertilizer grade and the raw material base have the most important effect on the quantity of dust formed in production. This was determined with grade 15-20-15, which Kemira Oy produces using several different formulations and processes. Special stress was laid on dust formation and the means to minimize it with regard to grade 15-20-15, produced with a process based on the use of dilute sulphuric acid. In this case the $(NH_4)_2SO_4$ crystals appearing in the slurry proved to be the cause of the dust formation. In the granualtion process these crystals tend to form brittle layers on the surface of the granules and then break down in the drying drum. The dust quantity has been reduced by changing the formulation, the granulation method and the granulation conditions.

Raw material impurities, such as those in MAP, have a rather clear effect on dust quantity and the granulation properties of the fertilizer.

The dust quantity can be affected to some extent by the process equipment. Of these, the most important is the granulator. The granulation method best suited to the formulation can improve granulation of the product and reduce dust quantities. The quantity of dust can also be reduced through the choice of the best process equipment, such as crushers and conveyors. The quantity of dust handled at Kemira Oy fertilizer plants varies today depending on the case, from 30 - 300 kg/product ton.

The losses, the amount of dust released into the environment and the cleanliness of our plant depend at first hand on the effectiveness of the dust recovery and collection equipment. Kemira Oy attemps to remove as much dust as possible from the gases in the dry form, for treating and returning the water used in wet collection to the process always causes difficulties. Cyclones and bag filters are used in dry collection of dust. Extremely good results have been achieved with bag filters in the collection of dust from cooling gas. The gas can be retuned e.g. to the drying drum furnace as dilution air and thus it is possible to recirculate gas to a certain extent - an achievement that benefits both environmental protection and energy economics.

The amount of dust released into the environment along with exhaust gases at Kemira Oy fertilizer plants has varied recently form 0.5-1.8 kg/product ton. The best results have been achieved at the newest plant, which is fitted with the dust collection equipment presented above.

Modern technology provides good prospects for the recovery and collection of dust. However, dust control should not rely entirely on up-to-date, efficient equipment. Choice of the raw materials and process suitable for the fertilizer grade can reduce the dust quantity and yield the best results when combined with today's dust recovery techniques.

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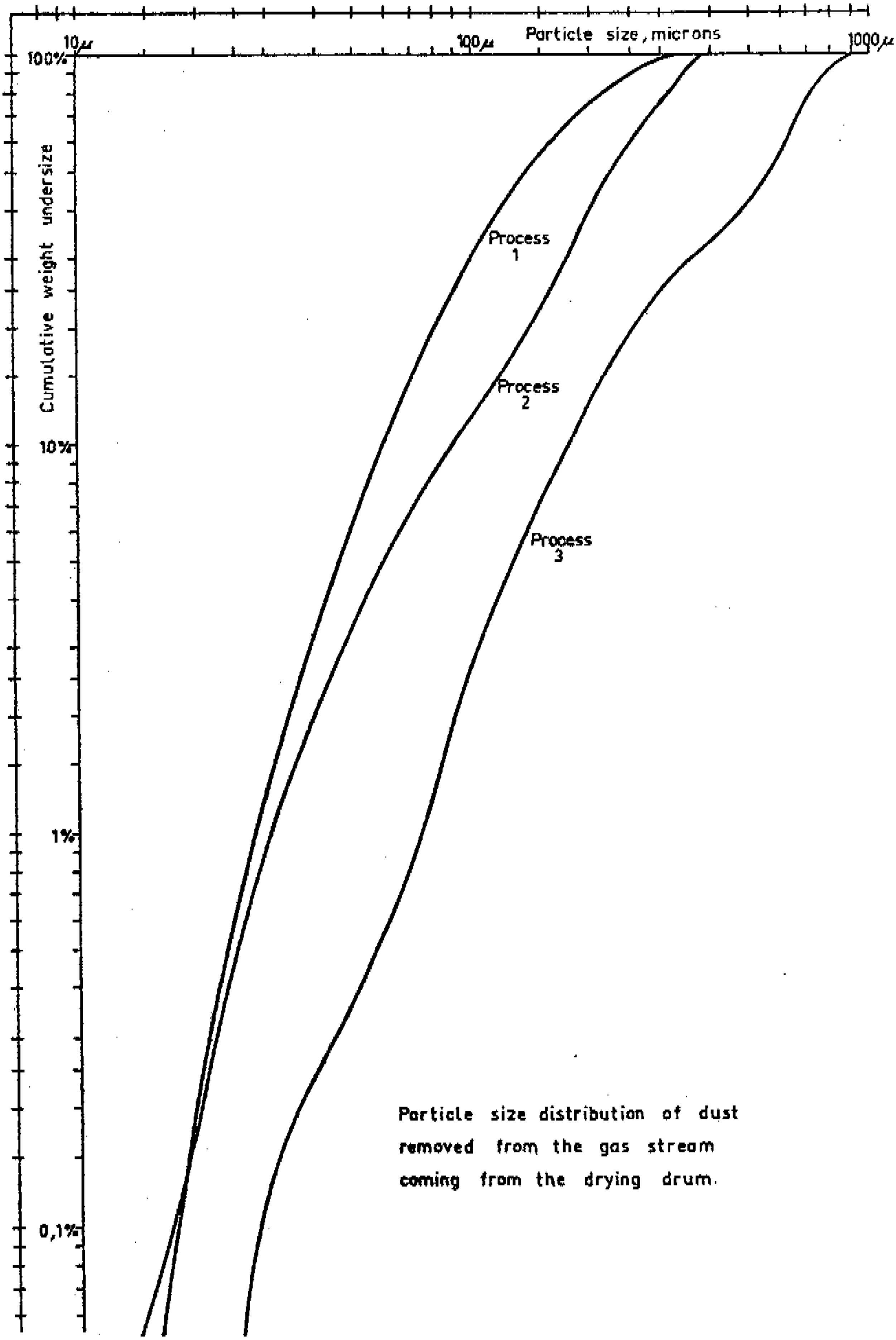
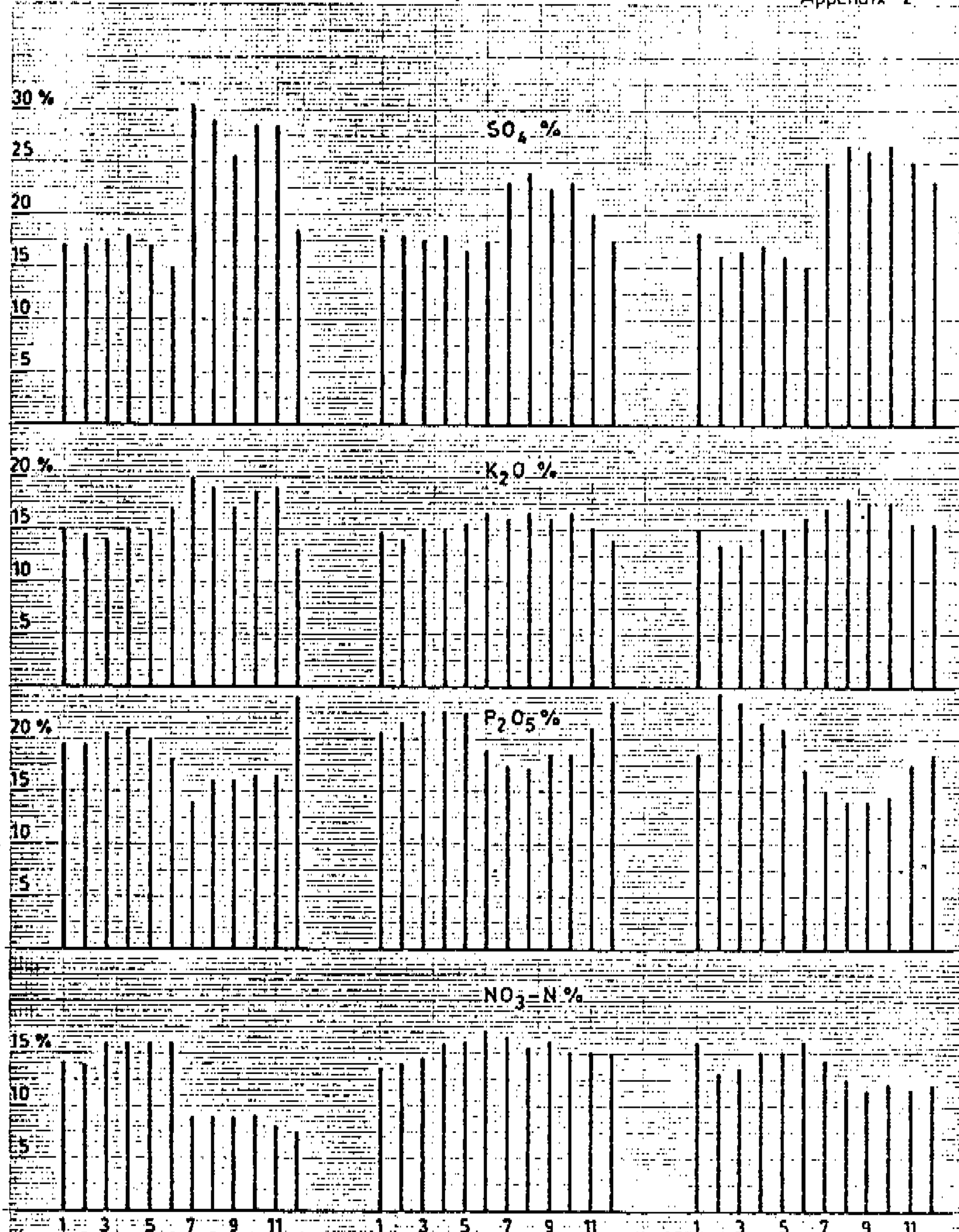
Appendix 1

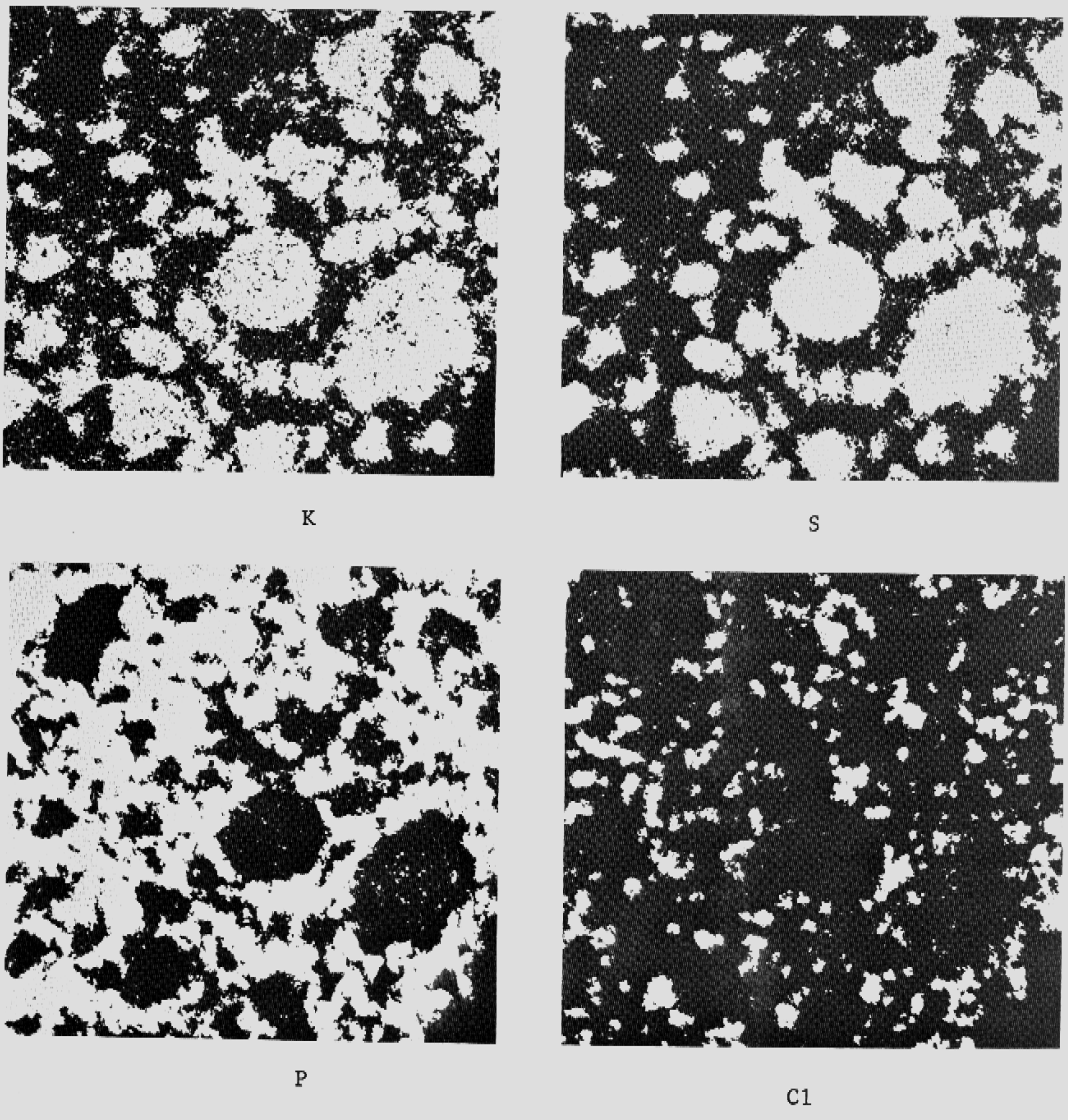


Particle size distribution of dust removed from the gas stream coming from the drying drum.



SO_4- and nutrient distributions in particles of different sizes in various process stages (process 1)

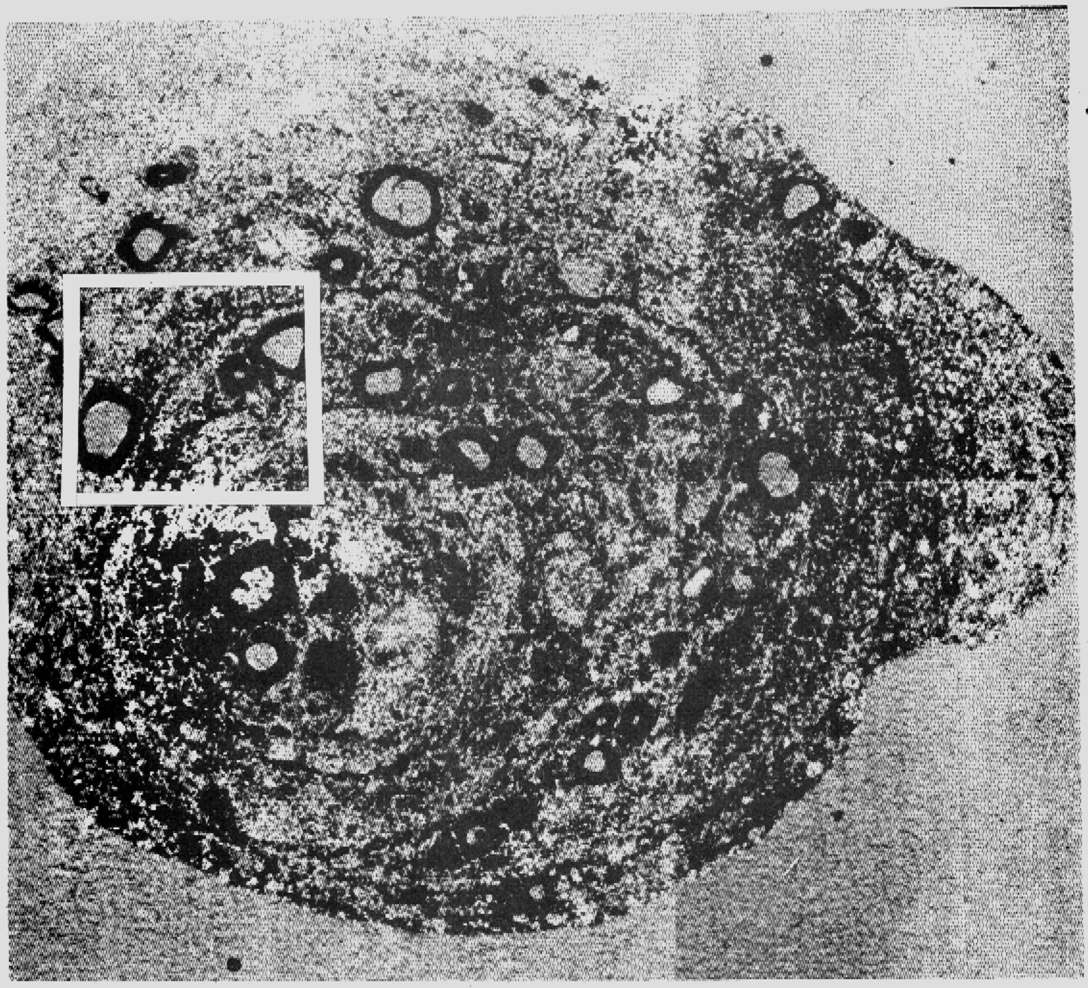
1. +7 mm
2. −7 +5 "
3. −5 +4 "
4. −4 +2 mm
5. −2 +1 "
6. −1mm +100 mesh
7. −100+200 mesh
8. −200+250 "
9. −250+270 "
10. −270+325 mesh
11. −325+400 "
12. −400 "



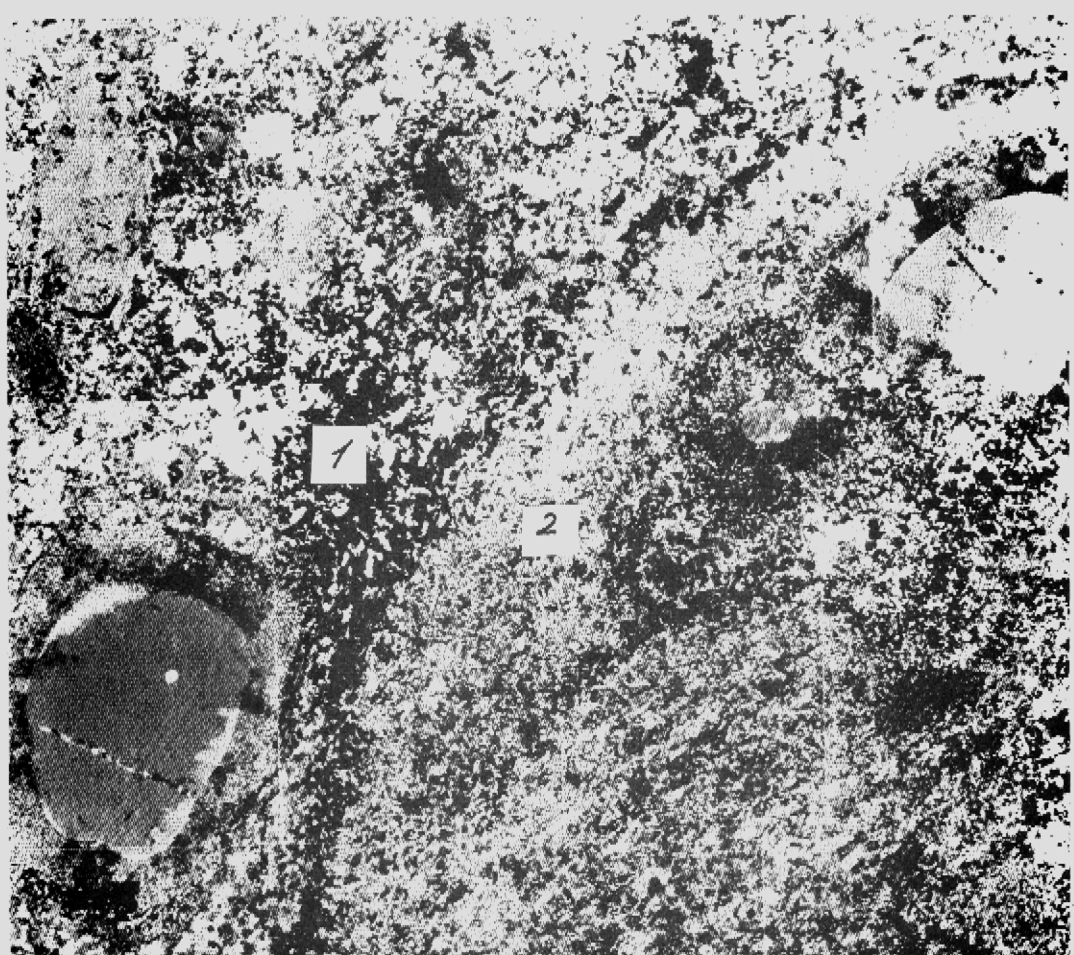
Maps of the distribution of K, S, Cl and P by X-ray microanalysis in part of granule 15-20-15 (Process 1).

The identical distributions of K and S illustrate loosely bound $(NH_4, K)_2 SO_4$ -crystals in the granule (magnification 250 x).

APPENDIX 4

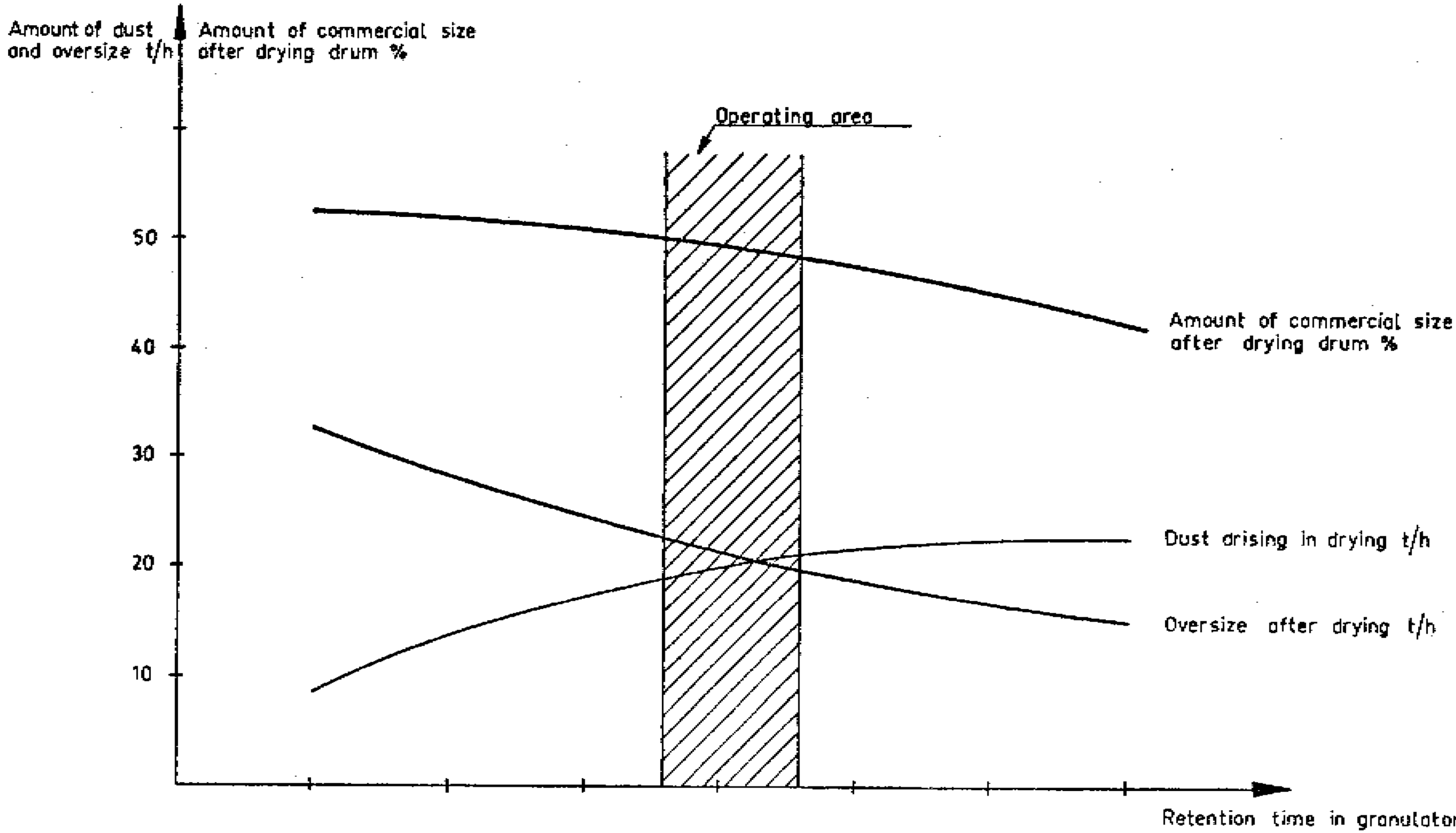


100 x



500 x

Micrograph of the thin section of granule 15-20-15 made by process 1.
The graph illustrates the granulating mechanism.
1. Loose layer.   2. Dense layer.



THE EFFECT OF RETENTION TIME IN GRANULATOR ON THE AMOUNT OF DUST, OVERSIZE, AND COMMERCIAL SIZE.

DISCUSSION

Mr. Suppanen (Kemira Oy, Finland)

Dust arising in the production of fertilizers is a fact well known to all of us and it forms one of the most serious problems in the manufacture of fertilizers. In our paper we have presented a dust problem in our Company, caused by grade 15-20-15 produced from a certain raw material basis, and explained the solution we have used. We have also expounded the solutions applied by Kemira Oy at their newest fertilizer plants for recovery and handling of dust and for achieving dust-free production facilities.

In our case the main reason for dust has proved to be the high amount of SO_4 in the formulation. There are in the slurry before granulation $(NH_4K)_2SO_4$ crystals. In the granulation these crystals form a fragile layer on the surface of the recycle granule and in the drying drum the granules are broken at this weak spot.

Slide 1.
The first slide shows the microphotographs of the thin sections of 15-20-15 granules made by various processes in our Company. To have clear contrasts, polarized light and the so-called quartz-plate compensator are used in the microscope. On the right is shown an ideal granule with almost no dust formation. It is made by phosphonitric process with spherodizer, in which nearly all the water soluble salts are in the solution before granulation. In the middle is shown a granule made by ammon phosphate process with pugmill granulation. Dust formation is moderate as can be seen in table 1. On the left is shown a granule with dust problems.

Slide 2.
Here we can see more distinctly that the granule with dust problems consists of 50-100 μ crystals in addition to the smaller ones that are like those in granules made by process 2. According to X-ray microanalysis they are $(NH_4K)_2SO_4$ and they are situated in loose layers, between which there are dense layers consisting of small-crystalline mass. This framed area is presented in more detail in the next slide.

Slide 3.
The framed area here with higher magnification permits to explain the granulation mechanism in this case as follows : when the slurry containing large $(NH_4K)_2SO_4$ crystals comes into contact with the recycle in the granulator, the clear solution penetrates the porous granule matrix and leaves coarse SO_4 crystals on the surface as a loose layer without binding agent. In the drying step the dissolved salts are crystallized as a fine mass forming a dense binding layer. The weakly bound SO_4 crystals form a weak point in the granule and break down in drying, producing dust.

Changes in the raw material base have clearly affected the dust quantities. The nature of gel-like insoluble phosphates in the raw material MAP proved to bear a clear influence on the quality of the granule and on the dust amount. MAP originating from dihydrate phosphoric acid proved to be better than that made of hemihydrate acid. The reason is the more gel-like structure in the former case- perhaps because of the higher Al-content of the phosphoric acid. The penetration rate is thus decreased and more binding agent remains in the coarse crystalline layer on the granule surface.

Slide 4
In this slide we can see a granule of grade 15-20-15 made from dihydrate MAP. Here it can be seen that the granule is more homogenous and that there are not so many loose and dense layers as in the granule in the slide before.

In the pilot plant test the ratio SO_4/NO_3 was decreased and $MgSO_4$ added to the formulation. The quality of the granules proved to be clearly better than in the control run with the normal formulation. The reason is - besides the lowering of the amount of $(NH_4K)_2SO_4$ crystallized in the slurry - also the favourable effect of KNO_3 and $MgSO_4$ on the granulation.

Granulation also has a very clear effect on dust formation. For this formulation the drum granulator suited better than the blunger. Due to the granulation mechanism, the retention time in the granulation drum had an effect on the formation of dust. With a long retention time a large amount of dust appeared, and granulation and the quality of the granule were bad. With a relatively short retention time the granule quality was quite good, but on the other hand there was a lot of oversize.

Slide 5.
In these scanning electron micrographs we can see the effect of the residence time in the granulator to the porosity of the granule. On the left there is the granule matrix of a fragile granule made by long residence time in the granulator, and on the right hand there is the granule matrix of a dense granule which is granulated with short residence time.

Despite all efforts dust is formed in the production of fertilizers, and finally it depends on the recovery and handling of this dust to what extent losses can be reduced, what the dust effluents are, and how dust-free our plant can be made. The aim of Kemira Oy has been to collect the dust and return it into the process in dry form, without the use of water. The benefit of this is that it makes it easier to control the plant's water balance, as a large dust quantity requires a lot of water and the amount of nutrient bearing water already tends to be excessive at a fertilizer plant.

For recovering dust from gases, we have used bag filters along with high-efficiency cyclones with a great deal of success. Bag filters have worked perfectly and with high efficiency especially when used for dust collection from cooling gases and general dust collection gases. For the wet collection of dust and for gas scrubbing we have recently been using floating bed scrubbers mainly.

In a fertilizer plant there are places where dust appears more than elsewhere. Such places are for instance the areas surrounding screens and crushers and the loading place of plant bins with solid raw material. In our Company we have separated those areas from the rest of the plant with simple walls and thus prevented dust and also noise from spreading to other parts.

As a conclusion we can say that modern technology provides good prospects for the recovery and collection of dust. However dust control should not rely entirely on up-to-date, efficient equipment. By the choice of suitable raw materials and a suitable process dust quantities can be reduced, and this together with today's dust recovery techniques will yield the best results.

Dr. Boos (Gewerkschaft Victor, G.F.R.)

All producers of solid fertilizers always face the problem of dust control in fertilizers. There are, in that connection, three important aspects :

1. Dust in fertilizer plants themselves, which, to ensure workers' protection, must be kept at as low a level as possible.

2. Dust discharged with waste gases from drying, cooling and dust control, which might create a pollution problem around the factory.

3. Dust which remains in the fertilizer after screening and coating and which may be a nuisance to the farmer during application.

If we consider that dust particle size is below 200 micron or rather 100 micron, then we find very large differences between the three above processes.

Indeed we all know that granulation processes are very complex and that many factors are involved. But we also know that dust settling is improved when the range of particle sizes is large and when granulation is designed so that inlet gases contain little dust. For that reason we would appreciate if the authors could give the range of particle sizes after granulator, dryer or spherodizer.

A dust production of up to 30 t/hr for a 30 t/hr output of finished product would, in my opinion, mean a very high recycle rate and, in fact, a very poor granulation.

Therefore it would be interesting to know the water content of the humid phase before and after granulation, possibly after drying as well as in the finished product.

The attempt to find an explanation for the poor granulation in the first plant is interesting with the formation of a double salt $K_2SO_4(NH_4)_2SO_4$. To avoid the formation of this double salt before granulation, did you try to feed dry KCl to the granulator ? In that way, as Professor ANDO stated yesterday, an increased caking might be expected, but its effect on granulation should be known if the mixture of salts or the double salt $K_2SO_4-(NH_4)_2SO_4$ is actually the cause of the poor granulation.

Mr. Suppanen

As we have presented our paper, there was really a lot of dust in our NPK plant. In the beginning we had really such big amounts as 30 tons per hour dust recycling in the process, and we started to study the granulation. When we changed our granulator from blunger to drum granulator the dust amount was reduced by 30% and it helped quite a lot at that time. Later on we made some optimization of the granulation and thus caused more oversize but it helped concerning this dust and, as I mentioned in my presentation before, the best help was the change of MAP raw materials used in the product.

For the first question of Dr. Boos he asked the screen analysis in different points of the process. Unfortunately we don't have figures after granulator. In any case I expect, I am quite sure that some granulation is also happening in the drying drum. After the drying drum we have 50% commercial size, that means from 2 to 4 mm, and in the final product we have over 90%. In the second question you asked the water content in different points of production. The water content of the slurry is quite constant, 13 - 14%. The water content in the granulator depends on what kind of MAP we have. When we used a MAP produced from hemihydrate-dihydrate phosphoric acid the recycle ratio was 1 to 5 and thus the water content a little over 3%. When we changed the MAP, and now we use MAP from dihydrate phosphoric acid, the recycle ratio was 1 to 7 and the water content in the granulation is now 2.5%. The water content of the final product is usually 0.5%. In the last question, I understood you asked if we tried to feed dry potassium chloride direct to the granulator. We have done this but we could not find any remarkable reduction in the dust formation compared to when we fed potassium salt in wet form. We think the advantage of feeding the potassium salt in the wet form is that we can have more homogeneous granules to prevent caking.

Mr. Gowran (N.E.T., Ireland)

I have a question on the cyclones. Could Mr. Suppanen tell us why they insulate these cyclones and also could he describe the type of air locks that they use and the cleaning equipments they use on the cyclones. Also he mentions in the paper about using air in the bag filter as dilution air to the drying drum. Would they recommend it where ammonium nitrate is used in the compound. This is from a safety point of view.

Mr. Suppanen

Why we have insulated our cyclones ? One reason is that we want to avoid dew point, and also in the summer when it is hot just to keep our plant cool and not to warm it. We use under our cyclones a double flat valve as air lock and then in our paper we have presented an idea to recycle the clean cooling air to the furnace of drying drum. Many years ago we have tested this thing but at the moment it did not succeed . We had too much dust. This is only an idea we have presented in our paper but as a matter of fact we are just now planning or designing some kind of system. From the former days I don't have any figures for the limitation of ammonium nitrate in the product. The ammonium nitrate content is usually from 3% up to 7%.

Mr. Quinton (Fisons, U.K.)

We find this an interesting paper with a number of useful ideas. However it would be interesting to have some indication of the monitoring system or organization that you have set out to ensure dust control procedures are maintained effectively. Do you for example have continuous monitors installed after the bag filters. Do you check the efficiency of the cyclones for example monitoring the ion concentration after the scrubber ? Do you consider that the 0.5 to 1.8. kg/t product of dust effluent to be the limit, for even lower values are achievable with more expensive equipment ?

Mr. Suppanen

We had tested some equipment just to control the dust amount after the bag filters and also after cyclones but this equipment did not work well. It was not reliable. At the moment we really don't have constant measurement of dust on the equipment and, regarding the question of dust effluent from our plant, we have mentioned in our paper that these figures are 0.5-1.8 kg/t. In our newest plant, where we use bag filters and also a scrubbing system, we can get this 0.5 quite easily. In our older plants we have this figure of 1.8 kg/t.

Mr. Peng (C.R.A. Brazil)

I'd like to ask the authors what kind of filter cloth do they use for the bag filter ? And do you find these bags sometimes get humidified and clogged ?

Mr. Suppanen

We use polyester as a bag material and we don't have difficulties with dew point when we are handling gases from cooling and general dust collecting system. But when we have handled gases from drying drum we have had difficulties with dew point, when starting our drying.

Mr. Moraillon (Générale des Engrais, S.A., France)

Could the author elaborate a little on the principle of the screen scrubbers and floating bed scrubbers he mentions in his paper ?

Mr. Suppanen

I could not understand what you mean with the screen scrubbers when we are speaking of floating bed scrubbers, the scrubber where we have little plastic balls and this washing liquid is going opposite the gas like ping pong balls. In this area scrubbing is happening. This is quite a commercial type of scrubber.

Mr. Moraillon

Then scrubber is the TCA scrubber. The French translation mentions a screen scrubber.

Mr.Suppanen

We have mentioned in our paper a screen tray scrubber. It means that there are some trays in the tower and the liquid is over the trays and gases going through the liquid.

Mr.Nielsson (I.M.C., U.S.)

I just want to make a comment. I heard that the gentlemen are going to take cooling air and put it into the dryer and I just want to tell them from experience that you may take the dust out of your plant but you end up with a plume all over Finland and other parts of the world, because any time you take a gas that contains nitrogen particles and put it through a drying combustion chamber, it all becomes blue haze and I think people tried it and tried it, but each time they had to stop it because they covered the country side with a blue plume. In fact in our plant we find that to bring in fresh air into the combustion chamber we have a pipe that goes outside the plant in order not to contaminate that air from within the plant, because the air from within the plant contains some dust and there is some nitrogen in it, so that when it goes into the combustion chamber it just becomes a cloud of nitrogen compound so that it covers the countryside. Then you get into another kind of problem.

Mr. Knudsen (Superfos A/S, Denmark)

I just wanted to comment to Mr. Nielsson that we do recycle not only the whole of the cooling air but also part of the air from the dryer, but of course it is not a primary air, but a secondary air. It is recycled as a secondary air to the spherodizer, so that it does not go to the burner.