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THE USE OF (N-P) SOLID RAW MATERIALS IN THE PRODUCTION OF COMPOUND NPK FERTILIZERS

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1. INTRODUCTION

It is almost a fact that the cheapest fertilizer intermediate materials (such as DAP) are produced either in places where local resources (phosphate rock, sulfur etc.) are available or where classical advantages of the economies of scale could be exploited.

This has led fertilizer producers who cannot benefit through either of the above, to develop alternative ways to reduce their production cost.

Typical example, is the situation in the United States where small producers use simple bulk blending facilities of solid raw materials to satisfy the needs of local markets.

Although this attitude is not widely accepted in Europe or elsewhere due to various reasons, it is still possible to produce reasonably cheap conventional fertilizers by optimizing mixing of raw materials liquid and solid.

This presentation refers to the experience of the Hellenic Chemical products & Ferilizers Co. in the use of solid raw materials such as ammonium sulfate, urea, DAP etc., in the production of compound fertilizers, either within a conventional plant or a within compacted fertilizer production unit.

2. THE HELLENIC CHEMICAL PRODUCTS & FERTILIZERS CO.

The Hellenic Chemical Products & Fertilizers Co. (HCPF) is the oldest Fertilizer Company in Greece, founded in 1909, with main activities in the mining and chemical sector including apart from fertilizers, acids, pesticides, flat glass and chemical products, as well as lead and zink sulphides and pyrite.

The annual production of NPK fertilizers is ca.700,000 metric tonnes most of which cover needs of the local Greek market which is of the order of 2,000,000 mt per year. The main fertilizer grades produced are 16-20-0, 20-10-0, 11-15-15, 0-20-0, 24-12-0, 14-14-14 etc. The raw materials used are :

imported anhydrous ammonia, sulphuric acid (produced from pyrites and sulphur), weak phosphoric acid 28% (produced from North African phosphate Rock), or imported strong acid 54%, potassium sulphate and various N or NP solid raw materials such as urea, ammonium sulphate, MAP/DAP etc.

The production of NPK fertilizers is effected in two conventional granulation plants equipped with pipe cross reactors as well as a new compacting plant which replaced an existing old granulation plant.

3. OPTIMIZING USE OF SOLID RAW MATERIALS IN A CONVENTIONAL GRANULATION PLANT.

Although relative prices of fertilizer raw materials vary considerably with time, it is easy to compare production vs. importation cost for intermediate raw materials such as ammonium sulfate, DAP etc. and therefore decide if for a certain period of time it is cheaper to import than produce these intermediates. In such a case, which is quite common for most of the time in the case of HCPF, one has to calculate the amount of these raw materials which can be used to minimize production cost, which at the same time does not affect quality of granulation and rate of production.

In order to fulfill the last two conditions one has to take into consideration two main factors which are : the water content of the feed raw materials liquid and solid, and the amount of heat liberated during the neutralization of phosphoric and sulphuric acid by ammonia in the pipe reactor and the granulator in general.

These two factors may be combined in a single number which we shall call :

Granulation Predictability Factor (GPF).

The physical meaning of this parameter is the amount of process heat available for evaporation of the water content of the feed materials.

Experience, after repeated tests and measurements, shows that if the GPF is slightly higher than the minimum heat required to evaporate the water (which theoretically is ca. 600 Kcal/Kg water) the whole quantity of water in the feed material will be evaporated and therefore the so called melt granulation will take place, provided that the quantity of water vapour is fully removed by the air sacked from the granulator.

In that case the results are excellent granulation (normal sized round granules) and minimum fuel consumption in the dryer.

If the GPF is much higher than the above mentioned critical value, granulation is poor (dusty small size granules) due to lack of sufficient water bridges.

If the GPF is much lower than 600 Kcal/Kg, again granulation is poor (overgranulation) due to the presence of excessive amounts of liquid water in the mixture coming out of the granulator.

That means, that for a given fertilizer grade, and set of raw materials, the maximum allowable quantity of the solid raw materials (ammonium sulphate, DAP etc.) to replace synthesis of these intermediates by reaction, and give the lowest possible production cost, can be determined by the quantitative combination of raw materials that satisfies the required value of GPF.

Thus the GPF can be used to optimize fertilizer production by determining that specific raw material combination which corresponds to the minimum cost and a good granule.

Moroever it can be used to predict granulation compatibility of any given set of raw materials, especially when new fertilizer grades are to be produced, which enables the operator to avoid unnesessary troubles during start-ups such as clogging, souping etc., or waste product and/or time to reach step by step the final operating conditions.

HCPF made extensive use of the above process design tool to determine optimum operating conditions when switching from the use of weak (28%) to strong (54%) phosphoric acid in the production of NPK fertilizers. In this case, since the amount of water in the feed raw materials decreases the GPF value is increasing, therefore, in order to obtain the optimum GPF value, it is possible to increase the percentage of solid intermediates (ammonium sulfate, or DAP) in the mixture.

4. COMPACTION : AN ALTERNATIVE WAY TO PRODUCE FERTILIZER GRANULES.

The mechanism of formation of fertilizer granules in conventional granulation is due to water bridges which contain the liquid phase of the fertilizer intermediate materials ammonium sulfate and ammonium phosphate. This corresponds to the granulation phase, followed by the drying step where-by water, is evaporated and the liquid bridges are transformed to solid crystalline salt bridges.

From the energy point of view this can be considered as a luxurious way of binding particles.

As an alternative to this, compaction of solid particles may be considered. In this case the binding force is due to Wan der Waals forces developed by properly pressing the raw materials. The granular product resulting after proper size reduction and classification does not have the perfect round shape of conventional fertilizers, but it combines several advantages which make it quite appealling.

The most important thing is of course that by this technology one can have the advantages that bulk blending plants offer (i.e. exploitation of various combinations of the cheapest raw materials prevailing each time in the market, with minimum installation cost charges) without having at the same time the agronomic problems that these blends might create due to segreggation.

Specific energy consumption per tonne of product is also lower than in conventional granulation plants, since in the case of compaction there are no drying or ammonia evaporation heat requirements.

Moroever, as the only pollutant present in the off-gases, is readily controlled dust, in contrast with classical fertilizer production units where the presence of fluorine and ammonia require the use of complicated gas scrubbing systems which end up with waste water effluents which have to be properly treated in a waste water treatment plant, one realizes how competitive and flexible a compaction unit becomes especially within hostile environments such as the one, the Hellenic Chemical Products and Fertilizers Plant is facing, being located just nearby a highly populated area.

Among other advantages of a compacting plant one should also mention the flexibility of switching from one product to another without considerable loss of material, and also the reduction of material losses (i.e. increased yield) which becomes particularly important in cases where use of valuable raw materials such as micronutrient salts is involved.

Of course, compaction of fertilizers does also present difficulties and problems which should be taken into account. The most important of them is the physical condition of the product. This does not refer to the case of caking which is a phenomenon that may equally well take place either in conventional or compacted fertilizers if anti-caking treatment is not effected. It mainly refers to the hardness (or strength) of granules which might be lower than that of conventional fertilizers for certain combinations of raw materials which of course should be avoided.

Another drawback of a compacting plant is that the size of the compactor (which is the heart of the plant) is not at the moment commercially available for production rates higher than 400 tpd which is relatively small compared to existing conventional kingsize plants.

Considering all the above, HCPF decided to replace one of its existing conventional granulation plants by a compacting plant having a capacity of 400 tpd.

The new plant cost about US.$.3,000,000 and is working since early 1987.
The flowsheet of this plant is shown in Fig.1.

As expected a lot of effort was necessary to obtain physically acceptable product (especially regarding strength of granules, a property measured by the dust formed by handling the granules) but as time passes experience is building up.

It took for example some time to realize that DAP based formulations give much better (stronger) products than MAP based ones. It was also verified that granule strength increases as the size increases which means that screen sizes should be properly selected to send lower than 2mm product back for compaction.

On the other hand the use of certain binding materials which might improre the physical properties of the product is under consideration.

5. CONCLUSIONS

The partial use of intermediate solid raw materials in the production of fertilizers can be a powerful tool of cost reduction provided that good granulation conditions can be maintained.

This, in the case of a conventional granulation plant can be effected by the use of a semi-empirical parameter the Granulation Predictability Factor (GPF) which depends on the water and heat balance of the system under consideration, and for that reason can reasonably well describe the behaviour of the system as far as granulation is concerned. Use of the GPF, after having established its critical value corresponding to good granulation which is ca. 600 Kcal/Kg of water content of raw materials, can lead to the choise of the lowest cost formulation.

For the case of compacted fertilizers it is difficult to establish an analogous simple tool to predict the conditions for good granulation, therefore one has to rely more on experience as far as combination of raw materials and various physical properties of them are concerned, in order to establish good granulation conditions. Still compaction is an alternative way to produce cheap fertilizers having the advantages of big conventional plants but not having the disadvantages of bulk blending products.

Regarding the economic criteria which will be used to compare synthesis vs importation of solid intermediates, it should be stressed that they can vary widely from one place to another, as they do not only involve the cost of the raw materials and intermediates themselves, but also production costs and various other local factors.

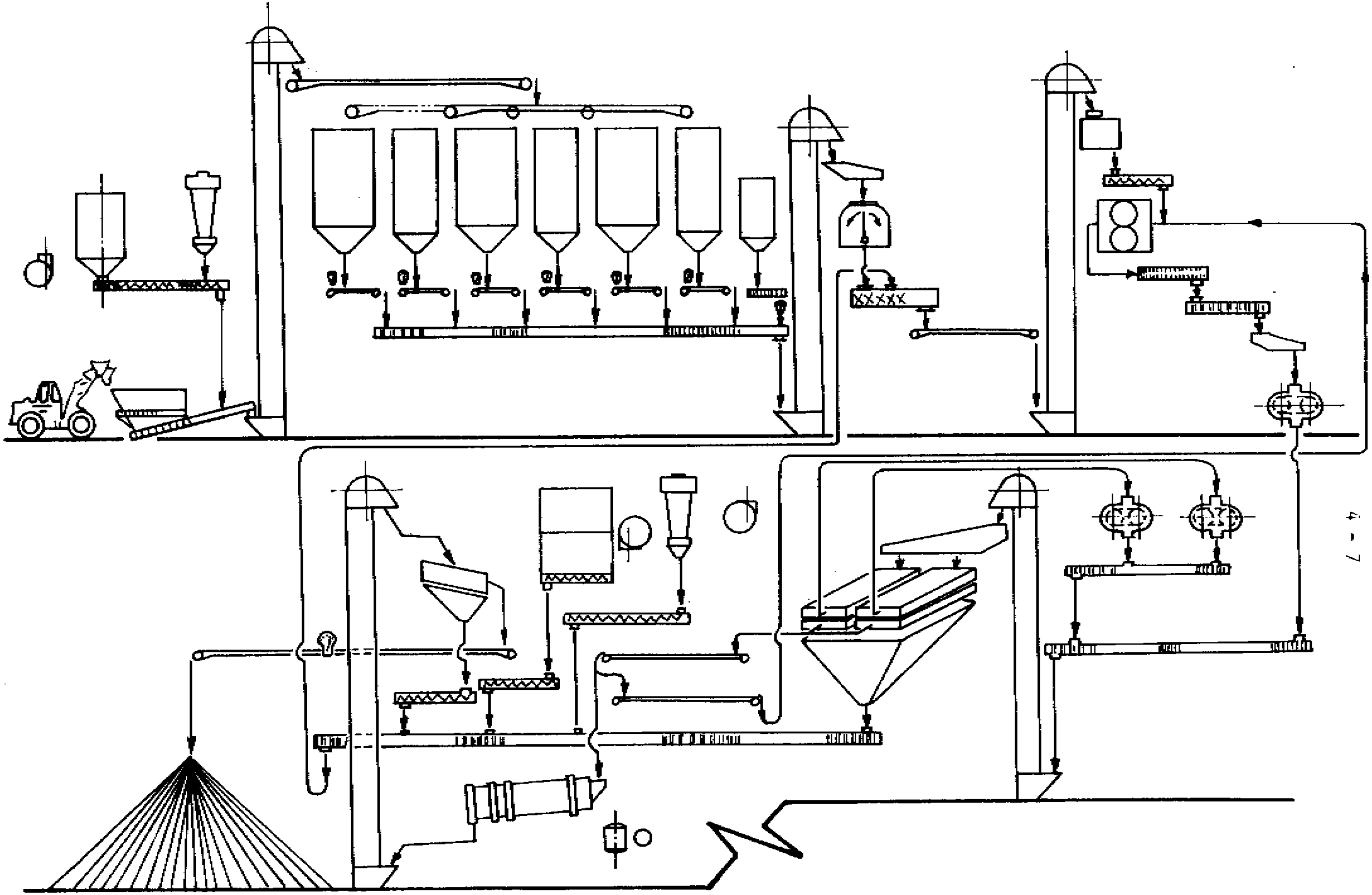

Fig. 1

Compacted Fertilizers Granulation Plant

TABLE 1

Granulation Predictability Factor (GPF)
for various fertilizer formulations.

Fertilizer Grade	Phos Acid Strength %	Kgs Solid AM.SUL / TONNE FERTIL	GPF Kcal/Kg water
20-10-0	28	0	1585
20-10-0	28	500	672
11-15-15	28	0	528
11-15-15	28	200	271
11-15-15	42	0	1169
11-15-15	42	200	618

TABLE 2

Typical formulations of conventional fertilizers with partial
use of solid raw materials vs. compacted fertilizers

Fertilizer Grade	RAW MATERIALS							
	Kg/T FERTILIZER							
	ANH. AMMONIA	UREA	AMMON. SULF.	SULF.ACID 100%	PHOS.ACID 28%	DAP	POTAS. SULF.	INERT
16-20-0/CV	151	-	170	286	729	-	-	65
16-20-0/CP	-	-	382	-	-	444	-	175
11-15-15/CV	134	-	-	274	547	-	300	45
11-15-15/CP	-	-	239	-	-	333	300	129
24-12-0/CV	123	207	200	266	437	-	-	-
24-12-0/CP	-	152	582	-	-	266	-	-

CV = conventional granulation product.
CP = compacted product.

TABLE 3

Physical Properties of Compacted vs. Conventional Fertilizers

Fertilizer Grade	Crushing Strength Kg	Abrasion Resistance %	Moisture Holding Capy %	Caking Tendency Kg
16-20-0/CV	4.1	1.4	2.5	-
16-20-0/CP	2.8	3.2	2.5	0.4
11-15-15/CV	2.3	3.9	6.8	0.9
11-15-15/CP	3.3	2.8	2.9	1.2

CV = conventional granulation product.
CP = compacted product.

TABLE 4

Strength of compacted Fertilizer Granules vs.Size (Abrasion Resistance %)

Fertilizer Grade	Screen size mm			
	+ 4	+ 3	+ 2	+ 1
11-15-15	6.8	9.6	22.0	33.9
11-15-15	0.9	1.8	2.4	8.7
14-14-14	2.8	3.6	5.8	9.2
20-10-0	1.6	2.7	3.2	8.9
24-12-0	1.0	1.5	2.4	6.5

TA/88/4 The use of N-P solid raw materials in the production of compound NPK fertilizers by N. Louizos, Hellenic Chemical Products & Fertilizers Co., Greece.

DISCUSSION (Rapporteur P.H. Moscham, Esso Chemical, Canada)

Q - Mr. T. KOIRUMAKI (Kemira Oy, Finland).

Why are compactors not available for production rates higher than 400 tpd, and have you made any development to improve the shape of the product, other than the polishing drum ?

A. Well, as far as the size of the plant is concerned, we could not find any compactor above this size on the market. I do not know why. Perhaps this is for historical reasons, but this is the biggest size that we could get, at least for fertilizer use. For the improvement of the shape of the product, we do have the polishing drum, as you mentioned, and we know that there is already developed technology for producing spherical granules, but we have not used this technology so far.

Q - Mr. K. GOVINDARAJAN (Southern Petrochemical Industries Corp., India).

Can you indicate whether the concept of GPF (granulation predictability factor) is applicable to DAP production in a pipe reactor ? If so, what is your experience with DAP production ?

A - Unfortunately, we do not produce DAP, so I do not have any experience of that or the concept of GPF in this case. But we can calculate this and see what results we would get.

Q - Mr. J.D. CRERAR (Norsk Hydro Fertilizers, UK).

Can you explain why DAP is superior to MAP for compacted fertilizers, what size range of feed is used and have you used Miniphos ?

2/ Also, have you any comments on the merit of powder MAP compared with DAP for conventional granulation ?

A - 1/ The first question concerning the use of MAP compared with DAP for compacted fertilizer is related to the second question about the size range of the feed we use. The DAP we use is granular DAP, whilst the MAP is not granular, so I suppose this is the reason why we get better product. We have used powdered MAP, but not Miniphos.

2/ On your second question, regarding the use of the same materials in conventional granulation, we have used these materials, but we did not see any difference apart from the difference in cost.

Q. Mr. F. KANGASTALO (Kemira Oy, Finland).

Could you use the granulation predictability factor in NPK process control, and what if the water content of the raw materials is varying over short periods ?

A - We are not using the GPF for process control. As explained previously, we are mainly using the concept of the GPF when we are going to switch from one formula to another, or from one raw material to another, but this is made only once, and after this we do not monitor the GPF continuously. Of course, this is something which could be done, but we

.../.../...

have found that it is not necessary. We try to keep more or less stable conditions during production. Now, if the water content of the raw materials varies in short periods, then it is likely to vary, say minus or more 1%. The GPF is not sensitive to this level of variation.

Q - Mr. F. CARVALHO (SAPEC, Portugal).

You refer to some economic aspects in the introduction to your paper. According to your experience, do you have any idea about the comparative production costs of a conventional granulation plant and a compaction plant ?

A - Actually, I think the answer is in the last paragraph of my paper, where I stated that, regarding the economic criteria, it should be stressed that costs can vary widely from one place to another, as they do not only involve the costs of the raw materials and intermediates, but also production costs and other local factors. So the answer refers to our case, and it is very difficult to translate it to other cases. Anyway, the production cost of a compaction plant, according to our experience, is less than the production cost of a conventional granulation plant. I would indicate a difference of the order of 5-10 dollar/ton. This includes the raw material costs.

Q - Mr. G. KONGSHAUG (Norsk Hydro, Norway).

As far as I understand, the granulation predictability factor (GPF) is a number indicating the energy balance for a given temperature and recycle ratio. In other words, a point on the granulation curve. Does this mean that you try to operate the plant at constant capacity, granulation temperature and recycle ratio, independent of raw materials and product grades ?

A - Again, I think the answer is similar to the previous question about the variation in the moisture, and I think the GPF is not very sensitive to the changes that you refer to here. I would say that this should be used only as a general guide when we have large changes in the production mode, but we do not use it for process control, or in the cases mentioned in your question.

Q - Mr. P. ORPHANIDES (Duetag, France).

In Table 4, you show the abrasion resistance of the product 11-15-15, which differs considerably. What is the explanation for these large differences in abrasion resistance ?

A - This is an extreme case, which I included in the table to show a very big variation. We have two different cases in the table, one is a normal case for 11-15-15, and the other is an extreme case to show that there is variation according to the screen size of the granules.

Q - Dr. S.K. MUKHERJEE (KRIBHCO, India).

1/ What has been your experience of onstream time of the compacting units ?

2/ What are the constituents of N-P-K in your compacted product ?

.../.../...

3/ Have you used urea and ammonium phosphate for the compacted granulation process, either for commercial or even for experimental runs ?

4/ What has been the experience of the caking properties of the compacted fertilizers ?

A - 1/ Regarding the operating time of the compacting plant, the plant has been working since last year, and I cannot say that we have any particular problems compared to the conventional plants that we operate. We have more or less the same downtime for the compacting plant as for a conventional plant.

2/ From an agronomic point of view, we have checked that the results that we get, using the compacted fertilizers, are the same as the results from conventional fertilizer. Also, the analysis of the granules shows that, more or less, you have the same constituents in either case. Of course, this depends on the method of mixing of the solid products and part of the equipment we have in the compaction plant is actually used to effect proper mixing of the raw materials. The mix that is fed to the compactor is properly mixed, so there is no possibility of segregation as we have with bulk blends.

3/ Regarding the use of urea and ammonium sulphate, we do use these products, and so far have produced fertilizer containing up to 15% urea, although I do not foresee difficulties in going further. The same applies to ammonium phosphates.

4/ The caking properties of the compacted fertilizers are the same, although this depends on the granule size. We try to have a very specific granule size product from the compaction plant. The compacted granules are strictly between 3-4 mm size, so that we do not have the small granules that would help caking. If the anticaking treatment is the same as with conventional granulation plants, there is no problem with caking of compacted fertilizer.

Q - Mr. R. HUTCHINS (Texasgulf Inc., USA).

In estimating the GPF, would you use the total water content in your feed materials, or just the free water content which would not include the bound water in, say, the phosphoric acid molecule or in the gypsum molecule ?

A - We use the free water and do not include the bound water.

Q - Dr. S.K. MUKHERJEE (KRIBHCO, India).

In the compacted process, did you have any experience of using nitrophosphates (from nitric acid decomposition of phosphate rock) with other constituents in making compacted fertilizers ?

A - No we do not have such experience.

Q - Mr. P. ORPHANIDES (Duetag, France).

You mentioned that, in the comparison of a spherical granule produced