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THE "ADELAIDE PROCESS" FOR THE GRANULATION OF WATER SOLUBLE SALTS

K.H. Walter

(Adelaide & Wallaroo Fertilizers Ltd., Largs North, South Australia)

1.0 SUMMARY

The ready acceptance of dry bulk blending in many parts of the world has created a demand for constituent fertilizer materials of excellent physical quality. Present compaction methods used for the production of granular potash salts and by-product ammonium sulphate result in granules of angular and irregular shape.

Whilst most fine powders are readily shaped into granular spherical particles by agglomerative processes, it was not previously possible to use this method to form stable spherical granules of such water soluble salts as potassium chloride, potassium sulphate, ammonium sulphate and langbeinite. In actual fact, each of these water soluble salts, on wetting in a tumbling bed of solids, forms a very fine wet crystalline pulp which refuses to coalesce and to form granules.

The principal theories on the mechanisms contributing to the granulation of powders by agglomeration do not offer any coherent explanation for this behaviour.

It was demonstrated by our work that the addition of a hydrophilic surface active agent and calcium sulphate hemihydrate to the water soluble salts allows the agglomerative granulation of these very soluble salts to be carried out in a typical N-P-K fertilizer granulation plant. This process makes possible the production of spherical regularly shaped granules of these fertilizer materials, which are ideally suited for the preparation of free flowing bulk blended fertilizers in which all constituents are substantially similar in shape.

2.0 INTRODUCTION

During the past few decades the fertilizer industry has witnessed an extremely rapid increase in bulk blending - the dry mixing of fertilizer materials. The ready acceptance of bulk blended fertilizers by the farming community was primarily due to the fact that in comparison with fully granulated N-P-K fertilizer mixtures, this operation allows considerable savings to be achieved in regard to costs of production, transportation and spreading. Apart from these cost advantages, bulk blended fertilizer materials give a great range of flexibility in nutrient ratios, which allows the preparation of a bulk blended fertilizer to suit the nutrient requirements of a particular soil.

The speedy acceptance of bulk blended fertilizers created a great demand for primary nutrient fertilizers having excellent physical characteristics and required the replacement of fertilizer powders by granular materials. Thus it is not surprising that a

major part of modern fertilizer technology is concerned with the production of spherical particles of desired physical characteristics in respect of particle size, particle strength, tendency to cake, sphericity and rheology.

In South Australia the sphericity of the particles of the fertilizer granules is of particular importance with regard to the rheology of bulk blended fertilizers. This is due to the fact that, compared to the U.S.A. which has a great number of bulk blending operations scattered strategically throughout the country and which blend the primary fertilizer materials and transport them over very short distances to the grower for immediate application, in South Australia and in most of the other States, the fertilizer manufacturer performs the bulk blending operation at the factory. Hence, the bulk blended materials may be transported by rail or road over several hundreds of kilometres to the consumer. We have found in the past that non-spherical fertilizer materials tend to pack closely during transportation and that their poor bulk flow properties can lead to severe problems during unloading. If bulk blended N-P or N-P-K fertilizers are to be transported over considerable distances, bulk blending is only a practical proposition as long as the primary nutrient carrying fertilizers are all well granulated with a close and also very similar spectrum of sizings. (1)

While the agglomerative granulation of fertilizer materials containing phosphates is comparatively straight-forward, until recently it has not been possible to form stable spherical granules of such water soluble salts as ammonium sulphate, potassium chloride, potassium sulphate and langbeinite by agglomerative granulation. In actual fact each of these compounds, on wetting in a tumbling bed of solids, forms a very wet crystalline pulp which refuses to coalesce and to form granules.

Adelaide & Wallaroo Fertilizers Ltd. found, (38) in its search for a method which would yield spherical granules, that the addition of certain surface modifying agents to the water-soluble salts prevents the formation of the wet crystalline pulp and allows the granulation of these water-soluble salts to occur. Letters Patent on this process have been granted in Australia and the U.S.A. and are pending in Canada, Europe and Israel.

Before discussing the research and the pilot plant work which led to the development of the "Adelaide" process for the granulation of water-soluble salts, this paper gives a brief description of some of the processes at present employed for the production of granular potassium and ammonium salts and devotes some attention to the fundamentals of agglomerative granulation.

The experience gained in production trials is then presented.

3.0 GRANULATION PROCESS

3.1 Present Processes for the Production of Coarse Potassium Salts

While relatively coarse potassium salts are commercially available, none of these coarse salts is formed by agglomerative

granulation. Some of the coarse salts of potash are produced during the beneficiation-flotation stage of the normal process, but the production of large crystals in this way adversely affect the recovery of the potash salts as well as the grade.

Another process relies upon the formation of large crystals during the process of crystallisation, but this considerably reduces the capacity of the crystalliser. In addition, impurities in the mother liquor impose limitations in regard to the particle size of the crystals and have proven troublesome during the operation of such controlled crystallisation processes. (2)

In view of the many shortcomings of these processes, which are not only economically inefficient, but also have serious product size limitations, the producers of these soluble fertilizer salts have been forced to develop some other means for the production of larger sizes. One of these processes employs hydraulically loaded high pressure compaction rolls for the production of dense flakes from the small particles of the feed. (3,4) These dense flakes are passed through impact-type crushers and then screened to separate the desired particle size range. The oversize is returned to the crusher and the screen while the fines are recycled to the compaction rolls. While this compaction process results in a particulate product within a desired size range, the particles are not spherical but angularly and irregularly shaped, and consequently the rheology of granules produced by the compactor process is not at all good.

3.2 Present Processes for the Production of Granular Ammonium Sulphate

Compactor processes have been and are being used for the granulation of ammonium sulphate, particularly that produced in crystalline form.

Another process, which was developed by the National Fertilizer Development Center of the Tennessee Valley Authority (U.S.A.) can only be used for the production of a granular ammonium sulphate. (5) In this process sulphuric acid and ammonia are pre-neutralised in a reactor to an $\text{NH}_3:\text{H}_2\text{SO}_4$ molar ratio of 1:1. The pre-neutralised fluid which usually contains less than 10% of free water, and has a temperature of about 150°C , is then fully ammoniated and granulated in a TVA drum granulator operating at a recycle ratio of about 1:1. The heat evolved during the ammoniation makes the drying of granules superfluous.

The granules discharged from the drum are cooled and screened. The over-size is disintegrated and recycled to the double-deck screen, while the fines are returned to the drum granulator. This process produces spherical granules, but its use depends upon the availability of cheap ammonia. In addition the ammonium sulphate produced in this manner is usually not competitive with by-product ammonium sulphate from coke ovens, the chemical industry (caprolactam) or the non-ferrous metal refining industry.

3.3 Agglomerative Granulation

3.3.1 General

The prior granulation processes for ammonium and potassium salts are either inefficient or provide a product exhibiting poor bulk flow properties. Except for the compaction methods, the existing granulation technology for ammonium sulphate is unsuitable for the production of spherical granules from fine crystalline by-product ammonium sulphate.

About 4 years or so ago Adelaide & Wallaroo Fertilizers Ltd. decided to perform some research into an improved method for the production of spherical granules from either fine potash salts or by-product ammonium sulphate by agglomerative granulation.

3.3.2 Definition

Despite the fact that agglomerative granulation is used on a very large scale in the fertilizer, cement and lime industries as well as in many branches of the metallurgical industry for the treatment of ore concentrates, there not only is a lack of knowledge in regard to the fundamental mechanism of this type of size enlargement, but also the word "granulation" is a generic term which can have different meanings to people working in different industries.

We in Adelaide & Wallaroo Fertilizers have chosen in the past a chemical engineering definition (6) which describes agglomerative granulation as "any process whereby small particles are gathered into larger permanent masses in which the original particles still can be identified." Unfortunately this definition is not very specific and for this reason we decided that within the framework of this paper we should use the definition of the "Institution of Chemical Engineers Task Unit on Granulation" (7) which describes "Granulation" as "The building up of clusters from powder or powder/binder mixtures" and "Agglomeration" as "The granulation by agitation or random motion of a bed of particles in the presence of the required proportion of a liquid phase and perhaps other binding agents."

This definition clearly excludes any process which produces granules by the fragmentation and classification of lump ore or employs classifying crystallization as is used by the potash industry.

4.2.2 Fundamental Principles of Agglomerative Granulation

The most important theories and hypotheses in regard to agglomerative granulation explain to a certain extent what is happening during this process. They do not, however, explain why very water-soluble salts will not coalesce during wetting and agitation in a bed of solids, but instead form a wet crystalline pulp.

In recent years research into agglomerative granulation has made tremendous progress and has developed many sophisticated theories and mathematical models in regard to the various factors controlling this technology.

Unfortunately, agglomerative granulation processes are used by many different industries, so that the fundamental knowledge is scattered throughout the literature, which makes it virtually impossible for an individual to gain a full knowledge of the literature on this subject.

The significance of the fundamental principles of agglomerative granulation led us to believe that we should first describe these principles and theories before discussing our own work on the granulation of water-soluble salts.

This description is more or less based upon the fundamental work performed by such works as Rumpf (8, 9, 10, 11, 12), Fuerstenau (13, 14, 15, 16, 27, 30), Capes (17, 18, 19, 20, 21, 22), Newitt (23, 24), Danckwerts (17, 21), Kapur (14, 25, 26, 27, 28, 29, 30), Ouchiyama (31, 32, 33, 34, 35, 36) as well as many others who cannot be mentioned within the framework of this paper.

Most employees of the fertilizer industry are aware that the agitation of solids in a pan or drum type granulating device accompanied by wetting will lead to an agglomeration of the solid particles.

In the agitated bed of wet solids the non-granular solids as well as the granules themselves are subjected to rather complex mechanical forces and stresses, which lead to the coalescence of the solid particles in the presence of the appropriate quantity of granulating liquid.

During the nucleation stage or the initial coalescence, the solid particles are mainly bonded together by the surface tension of the granulating liquid, as the tumbling or cascading of the solid particles continues, the originally large pores within the granules are considerably reduced in size and partially or completely filled with fine particles, while liquid which is forced out of these pores onto the surface of the granules picks up additional solids thereby increasing the size of the granules. At the same time the surfaces of the solid particles in the granules are brought sufficiently close together to allow the much stronger surface forces or forces of adhesion to give the granules additional strength. Additional tumbling rounds off these agglomerates and produces more nearly spherical particles. The combined action of surface tension and adhesion is responsible for the mechanical strength of the granules in their wet state.

Despite the fact that the complex forces in a tumbling and cascading bed are difficult to study, we know from our own research work and the practical experience gained during the agglomerative granulation of fertilizers, as well as from the literature, that the greater the mechanical force upon the granules in the granulating device, the lower are the requirements in regard to granulating liquid and the greater is the mechanical strength of the granule.

In addition it was established that there is an optimum particle size distribution for solids to be agglomerated. Generally speaking we can state that solid powders having a wide particle size spectrum, that is those where there is a range of sizings right through from

very fine to coarse particles, are easier to granulate by agglomeration than powders with a narrow particle size spectrum or in other words a powder made up of particles having very similar particle diameters.

It is thought that the effects of the particle size distribution upon the coalescence of solids and particle strength are due to the fact that the void spaces or pores formed by the large or coarse particles are occupied by medium sized particles, while the pores formed by medium sized particles are filled with fines, thereby considerably increasing the surface to surface contact between the individual particles forming the agglomerate and thus leading to a high degree of adhesion within the granules.

4.3 RESEARCH INTO THE AGGLOMERATIVE GRANULATION OF WATER SOLUBLE SALTS

4.3.1 Granule Strength and Granule Strength Testing Methods

There can be little doubt that the strength of the granules represents not only the major criterion for product quality in regard to granular products, but it also represents an important measurement in research into agglomeration.

Granule strength testing methods can be broadly classified into research test methods and routine testing methods. The first group of methods yields information in regard to the fundamental nature of the bonding by measuring the tensile strength of the granule. The tensile strength can be measured directly by determining the load required to achieve a deformation of the granule or indirectly by either compression tests or indentation tests. These direct testing methods are, however, extremely cumbersome and time consuming and could not be applied on a routine basis.

The second group of testing methods comprises arbitrary methods and are from a fundamental point of view, not well understood. Nevertheless, these arbitrary methods, which are extremely simple, fast and reproducible have found ready acceptance within industry. The second type of testing methods measures such physical characteristics as attrition, impact and dissolution of particles during a certain test procedure.

4.3.2 Granule Scrub Test

In our own work on granule strength, we have used "The Scrub Test Procedure" of the Amax Chemical Corporation. This test procedure is based on the attrition encountered in a tumbling bed of granules. The scrubber consists of a mild steel cylinder having a diameter of 150 mm and 200 mm long. The shell of the cylinder is equipped with four flights (6 mm mild steel bars).

Two removable end plates keep the granules within the rotating cylinder during the actual scrubbing test. Speed of rotation is 85 r.p.m. which is 78% of the critical speed. (Critical speed is the speed at which the centrifugal force upon a particle equals the force of gravitation). While the "AMAX" Scrubbing Test is an arbitrary test procedure, we have found that it possesses a good reproducibility.

By determining the size distribution of the granular material before and after the scrubbing test, we can assess the strength of the granules by the relative change in the proportion of material retained on successive test sieves. The smaller the change in the sizing, the harder are the granules.

4.3.3 Adelaide & Wallaroo Fertilizers' Research Results

As stated before, any past attempts to employ conventional agglomerative methods for the production of granules from highly water-soluble salts were not successful. Although it is still somewhat an open question, we may postulate that in such water-soluble salts as potassium chloride, potassium sulphate, langbeinite and ammonium sulphate the failure of fines to form granules on wetting in a tumbling bed is clearly related to the surface charges of these highly soluble crystalline materials and their small specific surface area which is a result of their non-porous structure.

We found in our research that the addition of calcium sulphate hemihydrate and a hydrophilic surface active material to the water-soluble salts prevent the formation of this wet crystalline pulp during granulation. Examples of materials used include attapulgite clay, bentonite clay, calcium or sodium lignosulphonates, casein, methyl-cellulose, agar, gelatine, aqueous dispersions of polyvinyl acetate or such water-soluble polymers as Sedipur, Aerofloc or Separan etc.

4.3.3.1 The Role of the Hydrophilic Surface Active Agent in Granulation

The hydrophilic surface active agent employed in our process, is added for the purpose of altering the surface charges on the solid-liquid interface which are responsible for the repulsion between the crystalline particles. It is thought that the hydrophilic surface active agent discharges the electrical surface charges of the crystals and thus allows the crystals to coalesce instead of forming a dispersed wet crystalline pulp. Potassium chloride, potassium sulphate, langbeinite and ammonium sulphate have relatively low surface energy, and the crystals of these salts are neither plastic nor deformable and have an extremely small specific surface area. Consequently, only relatively weak forces of adhesion per unit area are available to keep the crystals together. The absence of pores in the crystals which could be filled by the granulating liquid during tumbling prevents the relatively strong forces of capillarity from making a contribution to the bonding between particles. This means, therefore, that only the interfacial tension of the liquid between two mating surfaces is available for bonding. These forces are apparently too weak to overcome the repulsive surface charges unless the hydrophilic surface active agent is present.

4.3.3.2 The Role of Calcium Sulphate Hemihydrate as a Granulating Aid

Calcium sulphate hemihydrate, which is a very fine powder with a considerably higher surface energy than the water-soluble salts,

increases the surface to surface contact area between the individual crystals and granules during agglomerative granulation. In addition, it appears that the respective syngenites of ammonia and potassium considerably improve the wet strength of the granules.

4.3.3.3 Granulating Liquid and Sizing of Feed Crystals

In our pilot plant work into the coalescence of water-soluble crystalline materials which had been previously ground for reasons which will be explained later, we used alternatively water, hot aqueous solutions of the salt and steam as the granulating liquid. We found that the use of a hot concentrated solution of the salt to be granulated instead of steam or water greatly assisted in the granulation of these salts. We consider that this was mainly due to the fact that the smaller sized crystal fractions in the feed, which have an extremely large percentage of the total surface area, dissolve very rapidly in the water or steam during granulation, but were not dissolved when a concentrated solution of the salt was used. The small crystals thus retained in the bed of wetted tumbling solids increased the surface to surface contact and produced a granule with a smaller void space.

These conclusions agree with the findings of Ludwig (37) who assumed that, since agglomeration is the opposite to comminution, the ideal size distribution of a feed to the granulator should consist of all the different size fractions produced during grinding. An absence of any fraction will interfere with agglomeration and produce poorly packed granules having a high internal void space. How much the proper size distribution can affect the coalescence and the ability of the wetted solids to form granules is demonstrated by the results in Table I.

In this work, langbeinite was ground to four different degrees of fineness. The unclassified langbeinite samples were then granulated in a small batch drum under identical conditions. The granules were dried and then submitted to a test for their strength (scrub test). The empirical test which was described previously is based on the fact that the weaker the granule the greater will be the amount of fines produced during tumbling in a rotating cylinder. This means that the smaller the gain in the fine fractions of a granular product, the stronger the granules.

TABLE I. EFFECTS OF FEED SIZING OF GROUND LANGBEINITE ON THE STRENGTH OF THE DRIED GRANULES

(Each result represents the mean of 7 batch granulation tests)

NOMINAL SIZING		% PASSING 0.15 mm			
		10	30	40	50
ACTUAL SIZING					
+ 0.71 mm	%	26.3	0.4	NIL	NIL
+ 0.50 mm cum.	%	51.5	11.4	4.2	NIL
+ 0.25 mm cum.	%	80.0	50.1	39.9	19.0
+ 0.15 mm cum.	%	90.0	69.7	58.1	45.5
+ 0.075 mm cum.	%	98.0	82.8	73.7	57.4
+ 0.053 mm cum.	%	99.4	96.5	92.7	77.3
		WOULD NOT GRANULATE	EASE OF GRANULATION → INCREASED		COALESCED VERY EASILY
STRENGTH OF GRANULES:- % WEIGHT GAIN OF THE -0.71 mm FRACTION			51.6%	38.6%	34.1%

4.3.3.4 Drying of Granules

During the process of drying, the granules became very strong and hard. In our opinion, the granule strength is mainly based upon the interlocking of crystal bridges between the individual particles of the closely packed granules.

4.3.3.5 Summary of Pilot Plant Research Work

Our small scale research work was carried out with a 300 mm diameter batch granulating drum. After completion of this work, a small 200 kg/hr pilot continuous granulating plant consisting of a drum, a drier and a cooler, showed that in granulating such water-soluble salts as by-product ammonium sulphate, potassium sulphate, potassium chloride or langbeinite, the quantity of hydrophilic surface active additive required may vary between 0.3% w/w to 2.5% w/w for good granulation. In addition we found that the greater the mechanical forces in the tumbling bed of the granulating drum, the less will be the amount of the hydrophilic surface active agent required.

To achieve good performance in regard to granulation, the hydrophilic surface active additive as well as the calcium sulphate hemihydrate have to be admixed intimately with the water-soluble salts. The amount of calcium sulphate hemihydrate required will vary with the size distribution of the water-soluble salts. With very coarse uncrushed crystalline water-soluble salt materials,

amounts as high as 10% w/w $\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$ were required to achieve satisfactory granulation. However, with fine crystalline water-soluble salt materials, the amount of the calcium sulphate hemihydrate may be as low as 0.5% w/w.

4.4 PRODUCTION SCALE TRIALS

After demonstrating the effectiveness of our process in small scale equipment, we decided the process should then be proved in full scale continuous production.

We therefore arranged trials using a typical agglomerative granulation plant, employing the following traditional arrangement.

i) Proportioning Section

This section consists of four weighbelt feeders for the proportioning of the raw materials and the ground and screened recycle stream. The weighbelts discharge the weighed materials onto the granulating drum feed belt.

ii) Agglomeration Section

The agglomeration of the water-soluble salts and their additives is carried out in a granulating drum. This drum is 7148 mm long and 1716 mm in diameter and is rubber lined - The rubber lining is fastened longitudinally to permit flexing of the rubber for the prevention of build-up.

The normal operating speed of this drum is 13 r.p.m. or 40.3% of the critical speed. The water of granulation is added onto the cascading bed of solids through two independently operated banks of sprays, which are located inside the drum about 300 mm from the inlet or feed end.

iii) Drying and Cooling Section

The green wet granules ex the granulating drum are fed via a steeply inclined chute into a rotary drum drier. The drier is of the cascading type and is about 21000 mm long and 2380 mm in diameter. Normal operating speed of the drier is 3 r.p.m. The drying air is heated by oil to about 200°C to 300°C in a separate furnace. Outlet temperature of the air as 80°C to 90°C.

The dried granules are cooled in a rotary cooler which is 12500 mm long and 1525 mm in diameter.

iv) Screening and Oversize Reduction Section

Cooled product is elevated to a screen circuit comprising inclined vibratory screens. Oversize is recirculated to the oversize screen via a disintegrator and bucket elevator. Product from the oversize screen is transported by twin screw conveyors to a double bank of fine screens.

Screened product is passed to storage and fine undersize is diverted to a four hopper and weighbelt feeder and

returned to the granulation circuit.

We were surprised at the remarkable ease with which the plant was brought on steam and the consistency in the sizing of the product.

Variations in granule sizing to obtain a particular and narrow size spectrum was easily accomplished by adjusting the water of granulation. Once these adjustments had been made the granulation process proceeded with minimum supervision.

There can be little doubt that our trial work in a conventional N-P-K granulation plant demonstrated that the "Adelaide" process for the granulation of water-solubles can be performed in any conventional agglomerative granulation plant such as those which have been designed for the granulation of N-P-K fertilizers from dry raw materials. The quality of the granules produced was excellent from a hardness as well as sphericity point of view. The greater the degree of agitation in the tumbling bed the harder the granules and the less additives required.

While the size distribution of the granular product is solely a function of the screening operation for the removal of oversize and undersize it has a dramatic effect upon the quality of the product in regard to its rheology, rate of dissolution, bulk density etc.

We found that by changing the oversize and undersize screen we were able to produce products having identical physical properties to our superphosphate and that these granular spherical potash and ammonium salts lend themselves better to bulk blending than the irregular and angular granules produced by the compactor process.

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TA/82/13 The "Adelaide Process" for the granulation of water soluble salts, by K.H. WALTER, Adelaide & Wallaroo Fertilizers Ltd., Largs North, South Australia

DISCUSSION : (Rapporteur, Mr. T. HEGGEBØE, Norsk Hydro, Norway)

Q - Mr. J.E. REYNOLDS, Grace W.R. & Co, USA

Reference is made to the importance of mechanical forces and increased agitation to the mechanical strength of the granules (pages 13-5, 9 & 11) and the amount of granulating liquid required.

1. How can agitation or mechanical forces be varied in a rotary drum?
2. Have the principles as discussed in your paper been applied to the shearing and agitation encounters of a pugmill? If so, what are the comparisons as to granulation efficiencies and strength of granules?
3. The necessity of intimate mixing of the calcium sulphate hemihydrate with water soluble salts is mentioned on page 13-9. How is this accomplished?
4. What are your experiences of granulating PK mixtures of low P and high K analyses to be used as base products in blending?

- A - 1. By decreasing the slope of the drum and thereby increasing the residence time in the drum. Residence time in the drum granulating device is normally 4 to 5 minutes.
2. Yes. We prefer a pugmill before the granulating drum. We have granulated ex-dun single superphosphate since 1961. We removed in one of our plants the pugmill for about one year; since the quality of the products deteriorated the pugmill was reinstalled.
 3. Ideally in a pugmill but it can be done in the granulation drum itself.
 4. None in regard to the process under discussion.

Q - Mr. J.Y. MERLETTE, Prayon-Rupel, Belgium

Granulation with or in the presence of calcium sulphate is well known, especially among the manufacturers using single superphosphate as the main phosphorus supplier. It can also serve as a filler in certain formulations.

I have three questions to put:

1. Did you notice any scaling in the dryer in particular and in the overall plant in general?
2. The recycled fines and oversize are stored after cooling. Why not recycle the hot product?
3. What happens when you have too much or too little recycle product?

- A - 1. Scaling was not worse than that which occurs in any normal N-P-K granulation plant.
2. The design of the plant does not allow the recycle of hot oversize or fines.
 3. We have operated the plant with and without recycle stream.

Q - Mr. J. LE PAGE, SCPA, France

Do you think your process (addition of hemihydrate and/or surfactants) can also be used to improve the resistance of granules of products such as TSP? Do you have experience thereof?

A - No, we have not tried to improve the granulation characteristics of TSP with our additives.

Q - Mr. J. WLODARCZYK, Prayon-Rupel, Belgium

What is the type of calcium sulphate hemihydrate used: α ou β ?

In case of α hemihydrate obtained in the manufacture of phosphoric acid, by which technique is this product dried and what is its residual moisture?

You state that the hemihydrate is used in very fine powder form. Is it ground? What is its granule size?

In which way do you incorporate very intimately hemihydrate and surfactant to the material to be granulated?

A - We do not manufacture phosphoric acid, and for this reason, we have not used it.

The material used by my firm is plaster of Paris. Since this $\text{CaSO}_4 \cdot 1/2\text{H}_2\text{O}$ is obtained by the calcination of the dihydrate, its free moisture content is nil.

The $\text{CaSO}_4 \cdot 1/2\text{H}_2\text{O}$ passes 100% a 200 mesh screen (BSS).

Either into a blunger or into the granulating drum. We prefer to have a thin shaft blunger in our granulating circuit.

