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INNOVATIONS IN SLURRY PROCESS GRANULATION PLANTS

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SUMMARY

Many recent papers have discussed low recycle processes using non-granular MAP and much has been said recently concerning melt processes. This paper points out the flexibility and economics inherent in the modern slurry process granulation plant, and covers in detail recent innovations in slurry process granulation technology and its present status.

The paper defines the slurry process for fertiliser granulation and contrasts it with agglomeration type processes such as those based on superphosphate and powdered MAP. It covers trends and practices in raw materials used including ammonium nitrate, urea, powdered MAP, and phosphoric acid. The paper emphasises the effects on the plant design of using urea and ammonium nitrate.

The paper also covers recent innovations for reducing recycle requirements. Emission and effluent control, including scrubbing practices, particulate emissions and tailgas scrubbing, is discussed.

Mechanical and plant arrangement improvements are detailed. Emphasis is given to a description of an innovation in plant configuration utilising an "aging" or "stabilisation" belt from the granulator to the dryer. Also covered are screening improvements, recycle control, and grinding changes.

Future trends are discussed.

I INTRODUCTION

The original Dorrco slurry process granulation plant went into operation in the early 1930's at Trail, British Columbia.

Many plants have been built over the intervening years. A list of recent installations is presented in Table 1.

II SLURRY PROCESS GRANULATION - A DEFINITION

The slurry process for granulation can be defined as the process of spreading a thin film of fertiliser slurry over a substantial surface area of recirculated particles and the subsequent drying. Application of successive layers of slurry results in enlargement of the particles and a hard, free flowing granular product.

The "original" Dorrco slurry process used the blunger as a fluid bed flash mixer for accomplishing the spreading or dispersing of the slurry. In the strict sense of the word, the blunger is not a granulating or agglomerating device. Granulation and particle growth occurs as a result of application of successive layers of slurry to recycle particles until they achieve the required size.

The basic objective of recycling the material is to control the film thickness of the wet slurry as it goes through the drying process. If one attempts to dry a film of ammonium phosphate slurry only a few millimeters thick, for instance in a pan in a hot box with circulated hot air, diffusion of the moisture out of the slurry slows down quickly because of the creation of a hard, dry impervious surface. It can take hours, even days to dry fertiliser slurry which is thicker than a mere film.

The maintaining of a fluid bed of solids under shear, as in a blunger or in a granulating drum is necessary for achieving a thin coating of slurry and a drier feed material which will dry in a matter of minutes.

Contrasted to the slurry process for granulation is the agglomeration process in which the P_2O_5 is predominantly present as powdered or microprilled MAP or run-of-pile triple superphosphate or normal superphosphate. Granulation occurs by the addition of small amounts of liquid phase and heat together with the rolling action of the granulator. Some agglomeration also occurs in the slurry process plants.

In forming granules using agglomeration techniques, liquid phase is trapped inside particles of product size range, usually about 1.5 to 4.0 millimetres. It should be evident that it is quite difficult for this moisture to be eliminated in relatively short drying times.

1. Drying Rate Curves

In pondering the variables affecting drying time, recirculation rates and fertiliser plant capital costs and in studying recent articles relating plant cost to recycle rates, it seems to us that the case for very low recycle rates is being put forth as virtually the sole element for judging a fertiliser plant's efficiency and by inference its capital cost and productivity.

Figure 1 is a compilation of drying rate data for four commercial Dorrco slurry process plants, producing 1:1:1 grades. Two of these plants use urea and two use ammonium nitrate for supplemental nitrogen. There is some interpolation and some extrapolation of the data as presented. The data has been averaged in order to composite the varying analytical techniques for moisture determination, different product particle size analyses, and different soluble impurity levels of the products, all of which can influence the reported moisture analyses. Recycle rates for the cases covered by these curves were in the 3:1 to 6:1 range.

The data from these four slurry process plants indicate that about 90% to 95% of the free moisture in the dryer feed material has been eliminated in 15 minutes. In contrast, drying rates for 1:1:1 grades reported in one recent paper (1) shows that an average of only about

70% of the free moisture in the feed is eliminated in 15 minutes. In another paper (2), reporting data for unidentified grades, only about 60% of the drying occurs in 15 minutes. No reference is made in either paper to the quantity of recycle being used. We suggest that slurry film thickness or put another way, the location of the moisture in the feed granule may be a significant variable in the drying time required and the size of dryer needed.

One significant trend in modern slurry process plants has been the move to design for shorter detentions in the dryer. For DAP and TSP, modern plants use much less than the 7.5 to 10 minutes formerly thought to be necessary. The fact that relatively low dryer detentions are feasible without loss of product quality, contributes substantially to the productivity of modern slurry process granulation plants.

2. Granulation Plant Control

In a comparison of the slurry process with the agglomeration process, it is important to consider the differences in operating control. In a typical slurry process granulation plant, the recycle is normally held constant. The recycled solids, consisting of some on-size material and fines, act as a base for drying a thin film of the feed slurry. Product take-out is adjusted to maintain a constant recycle. Recycle control can be made automatic.

In a plant feeding substantially dry P_2O_5 such as non-granular MAP, ROP, TSP or ROP normal super, the objective is to take all the product size material out as it is produced. Otherwise, any solids recycled require additional steam, process heat and/or liquid phase, and consequently more dryer fuel. Ultimately plant capacity is reduced. This is a fundamental difference in the operation of a granulation plant where granulation (agglomeration) is controlling. While all fertiliser granulation plants rely on operator "art" or skill for maximum efficiency, it would seem that a plant in which granulation efficiency is capacity controlling is all the more dependent on this intangible element.

In addition, it can be readily seen that if the agglomeration process plant is willing to accept a wider spread in particle size for its product, it can achieve a higher capacity. Product particle size is not always critically important but it may be crucial in a competitive or export market.

In the Jacobs-Dorrco slurry process it is preferred to operate where the moisture balance or recycle is capacity controlling rather than where granulation efficiency controls. However, recycle can be as low as 2:1 to 4:1 in NPK plants. The original slurry processes did use 10:1 or even higher recycle rates, but modern slurry plants have substantially reduced this, as we will discuss in detail later in this paper.

Positive process control and the ability to take out a fixed quantity of product hour after hour has resulted in a high productivity factor for slurry process plants. Because of the flywheel effect in the slurry process, many process upsets can be handled as a matter of routine. In addition, product analysis deviations can be held to a minimum with products closer to target grade.

III RAW MATERIAL TRENDS IN SLURRY PROCESS PLANTS

Granular fertiliser products continue to increase in plant food content. The Dorrco slurry process was one of the first to use ammonium nitrate and urea in substantial quantities. A list of installations and some of the products is given in Table 1. The trends in the use of ammonium nitrate or urea are, in general, toward a reduced water load for increased plant capacity.

1. Ammonium Nitrate

In the Jacobs-Dorrco slurry process, ammonium nitrate solution is evaporated to 98% to 99% solids in a conventional evaporation system. The slurry is then introduced into the preneutraliser where it serves to reduce the viscosity of the ammonium phosphate slurry formed there. Ammoniation is carried out to 1.4 mole ratio or so, and cooling air is applied to smooth the ammoniation violence and reduce the temperature to below 140°C. The composite slurry, at 90% to 96% solids depending on the ratio of ammonium nitrate to ammonium phosphate is pumped to a rotary drum granulator. Where products containing mole ratios other than about 1.4 are desired, addition of 54% acid or NH_3 to the granulator can increase capacity by dryer. 30% P_2O_5 acid is fed to the scrubbing system, with the overall composite feed acid strength being 45% to 46% P_2O_5. This, somewhat higher strength acid than formerly used, is to provide for tailgas scrubbing for maximum recovery of NH_3, P_2O_5 and K_2O.

2. Urea

The use of urea in granular NPK fertiliser is increasing. Several large slurry process plants have been built and described in the literature including the Madras Fertilizers Plant (3)(4), which makes principle grades 17:17:17 and 14:28:14. Over 1,000,000 tons of urea-NPK granular fertilisers has been produced in this plant and on the basis of its performance, construction of a third line is currently being completed. In addition, a large two line slurry process plant for urea-DAP grades is being completed in Korea.

The Jacobs-Dorrco slurry process for urea-NPK grades is based on the DAP slurry process with modifications to handle the urea. The basic elements have been well covered in the above references dealing with the Madras plant. However, we would like to mention a point or two here. Recycle rates for 17:17:17 are in the range of 3.0:1.0 to 3.5:1.0. The plant uses liquid ammonia and solid prilled urea. Recycle rates, although they are relatively low now, could be reduced further by the use of gaseous ammonia and a urea melt, both of which would tend to permit granulation at higher temperatures using less water.

In our opinion, the key to a successful slurry process plant for urea-NPK formulae is the DAP basis. Ammoniation in the granulator provides heat for accomplishing granulation at a low moisture level and at the same time heat for evaporation of water from the film on the surface of the granules. The Jacobs-Dorrco process is virtually isothermal with respect to the solids so that melting and scaling in the dryer is avoided.

Table 2 summarises the characteristic figures of the Jacobs-Dorrco slurry process for 17:17:17.

The following advantages are claimed for the slurry process for producing urea based NPK grades:

1. <u>Lower Formula Costs</u>

   The DAP Product formula for the slurry process contains more ammoniacal nitrogen. It is probably not practical to make DAP based urea grades starting with all dry MAP as the P_2O_5 source.

   About 5% more urea is required for MAP based 17:17:17 resulting in up to $2.00/T of product extra formula cost. Also the problems associated with the use of urea are less for DAP grades since less urea is used. Some grades, such as 10:26:26, 10:30:20. 12:32:16 and 14:36:12 contain little or no urea using a DAP formula and can be processed as normal NPK's at very high rates. Other grades such as 10:20:30 and 12:24:24 have only about 6% or 7% urea using a DAP base.

2. No Sulphuric Acid Required

Solid MAP based processes require the use of concentrated H_2SO_4 in the granulator to maintain reaction heat. This is an expensive form of heat and the sulphate radical reports in the product diluting the overall concentration. Sulphuric acid is also likely to decompose significant quantities of urea resulting in the formation of particulate fume particularly with chloride present. This fume is difficult to remove from the vent gases.

In the slurry process no sulphuric acid is required.

3. No Raw Materials Preparation Required

Raw materials feed preparation is nil. Prilled or crystalline urea can be used and particle size is relatively unimportant. This is desirable as it is not easy to grind urea. No identifiable urea prills are evident in the product which is relatively homogenous in physical appearance.

4. Superior Physical Properties

Urea-NPK's are relatively soft and hygroscopic, so it is important to produce to best possible standards. From the data available, the physical properties of slurry process urea-NPK grades appear to be better than competitive materials.

Crushing strength according to published (1)(4) is higher. Slurry process NPK products based on DAP formulae registered critical relative humidities of about 55%, as tested by T.V.A. on the products of two producers, the grades being 17:17:17, 14:28:14 and 16:20:16. This is somewhat higher than had been expected for urea-ammonium phosphate-potash formulations. T.V.A. Test Data for 14:28:14 and 17:17:17 is shown in Figures 2 and 3. The latter figure compares moisture absorption and depth of wetting with nitric phosphate 20:20:0, prilled urea, prilled ammonium nitrate and granular DAP.

5. Product Chemical Composition

Product grade analyses are likely to be closer to specification, using the slurry process, because product take-out is constant. This is particularly important for materials bagged immediately off the line as urea grades often are, since there is no pile to average out product variations.

6. Low Stack Emissions

Phosphoric acid and water are available for scrubbing so that emissions are extremely low. Fugitive and measurable dust losses are nil.

7. Lower Strength Phosphoric Acid Used

Even when water is used for tailgas scrubbing, composite feed phosphoric acid strengths will be in the range of 42% to 46% P_2O_5. Therefore, less evaporation is required for the slurry process and in addition, no MAP processing or storage facilities are required.

3. Solid Form of P_2O_5

Solid forms of P_2O_5, such as normal superphosphate and run of pile triple superphosphate have been used to some extent as part of the raw materials of slurry process plants. Several plants have reported using run of pile triple superphosphate in slurry process TSP plants. This has the effect of granulating the ROP together with the fresh slurry process TSP and the recycle rate is substantially reduced. One plant reported reducing its recycle from 8:1 to 4:1 by this means (5). At the same time a substantial increase in capacity for the product TSP from slurry was registered.

Powdered or prilled MAP can, of course, be used as a raw material in slurry process plants. There are circumstances where the addition of nongranular MAP can be attractive. These are for products high in P_2O_5 where liquid phase and recycle requirements are normally high. The experience of one Dorrco slurry process plant in using non granular MAP is related in reference (6). In that operation, there was difficulty in achieving mole ratios above 1.65 where 75% of the P_2O_5 came from MAP.

The use of non granular MAP to supplement acid P_2O_5 in making DAP has been reported by Swift in reference (7). While this appears to be attractive, for a portion of the P_2O_5 source, it is likely that excessive use of non granular MAP will result in the inability to make products as high in mole ratio as those made from phosphoric acid. The trends in raw materials will be to increase use of solid forms of P_2O_5 in cases where this will increase the productivity of existing plants.

IV REDUCTION OF RECYCLE AND LIQUID PHASE IN SLURRY PROCESS PLANTS

The fact that a substantial recycle of particles is required for spreading the slurry into a thin film does not preclude one from making every effort to reduce the recycle and the liquid phase to improve the economics of the slurry process. Some of the techniques used to accomplish these objectives have been mentioned previously in this paper. They fall into two areas: (1) Steps available to permit handling more water and liquid phase per ton of recycle and (2) Steps available to reduce total water and liquid phase per ton of product.

Techniques for Carrying Higher Liquid/Recycle Ratios

1. TVA Type Granulator vs. Dorrco Blungers

   Initially slurry process plants using blungers for TSP required 10:1 or 12:1 recycle and for DAP 8:1 or so. Using the granulating drum for these processes recycle ratios are reduced to below 8:1 for slurry TSP and 5:1 for DAP. Evaporation achieved during granulation accounts for the difference, effectively partially drying the liquid film on the surface during granulation. The effect can be enhanced by the use of a countercurrent air sweep in the granulator. This can present problems on some grades because of dust carry out. A technique to overcome the latter problem is to inject cocurrent air by means of a blower which is done in some plants.

   A factor which assists in the reduction of recycle using the rotary granulator for DAP is the higher extent of ammoniation it is possible to achieve against that obtained in blungers. Several recent Dorrco granulation plants have two lines, one with a TVA granulator, the other line using Dorrco blungers.

   Each line was designed to process specific grades.

It has been possible to observe the characteristics of both devices as granulators or slurry dispersors.

DAP can be made at quite high rates at a pH of 7.6 or above in a TVA type drum. If we study the titration curve for a typical Florida acid (Figure 5) this appears to be above 1.9 mole ratio. The reporting of mole ratios, incidentally, is not as precise as one might expect.

For blunger ammoniation, pH's of 7.2 to 7.3 are normal mole ratios being about 1.80-1.85. Above this, ammonia losses become excessive. The little extra drying effect and the reduction in liquid phase solubility by the slightly higher ammoniation possible in the granulating drum results in higher throughput of DAP per ton of recycle. The bias toward the granulating drum for DAP is not as noticeable at lower operating rates or when making NPK's like 17:17:17 where the ammoniation required during the granulation is low.

2. Use of Gaseous NH_3 in the Granulator

The use of gaseous rather than liquid NH_3 in the granulator will increase the reaction heat and evaporation in the granulator, tending to increase capacity for a given recycle rate. However, at very high ammoniation rates and high product pH ammonia loss to the scrubbing system is higher.

3. Supplemental Use of Non-Granular MAP or ROP TSP

Several cases where nongranular MAP and ROP TSP have been used to supplement acid P_2O_5 have been mentioned previously under Raw Material Trends. The use of ROP in slurry triple is a somewhat specialised case although it represents an interesting revamp possibility to those operating slurry process TSP plants.

The use of judicious amounts of nongranular MAP can increase plant capacity in probably some slurry process plants, particularly those making 1.0 to 1.4 mole ratio products.

Techniques for Reducing Liquid Phase and Water Load

Several techniques have evolved for reducing the viscosity and increasing the solubility of slurries to be handled and thus to be able to use constantly higher P_2O_5 content acid. Some of these are as follows:

1. Granulate with slurries below 0.5 mole ratio or at about 1.4 mole ratio where solubilities are at maximums.

2. Feed part of the feed acid to the granulator as 54% acid. This is done in several plants where MAP formulae are made after granulating with 1.4 mole ratio slurries.

3. Minimise the use of ammonium sulphate in the slurry, because this is a relatively insoluble material and when incorporated in a phosphate slurry, the slurry can carry only 70% to 75% solids instead of about 85% solids for a 1.4 mole ratio ammonium phosphate slurry.

4. Advantage can be taken for the increased solubility of slurries containing ammonium nitrate, as discussed earlier in this paper. Therefore, it makes sense to use highly concentrated ammonium nitrate, 98%-99% solids and introduce this into the preneutraliser. A number of suggested means for reducing recycle ratios in high analysis NPK's is covered in Ref. (8).

5. The use of high temperature ammonium phosphate slurries. A pressure reactor has been suggested by one process supplier. Obviously, there are potential capacity advantages if product mole ratio and ammoniation efficiency are not seriously effected.

   Another approach is to use a Tee reactor which in a sense serves as a pressure reactor. Normally in the Jacobs-Dorrco DAP process about 25% of the P_2O_5 fed is required in the scrubbing system as 30% acid and some 30% acid is fed to the preneutraliser along with 54% acid to make up an overall feed mix of about 38% to 40% depending on whether liquid or gaseous ammonia is used. If the P_2O_5 normally fed as 30% acid to the preneutraliser is replaced by 54% acid which is mixed in a T reactor with gaseous ammonia and the resulting melt fed to the rotary drum granulator there is a potential increase in capacity of 30% to 35% based on the water balance. Such Tee reactors are in commercial scale operation in TVA's melt process demonstration plant. The effect of supplementing the normal DAP process with a T reactor is to increase the composite phosphoric acid strength that can be handled and reduce the water to be removed.

A more recent TVA development is a pipe cross reactor (9) in which sulphuric acid at 93% and phosphoric acid at 50% P_2O_5 and gaseous ammonia with a small amount of water are added to a pipe cross reactor. The product is then directed into the granulator. Commercial scale operations have been conducted with mono ammonium phosphate grades, 12:48 and 6:24:24, in which about 1/3 of the P_2O_5 is fed through the cross reactor. Using either the cross or the Tee reactor, the water vapour is flashed off as the slurry or melt is discharged into the granulator, and carried off in the vent gases.

Both the Tee reactor and the pipe cross reactor appear to be potentially capable of substantially increasing the capacity of slurry granulation plants. However, these techniques appear to be demonstrated mainly on mono based grades at present.

V EMISSION AND EFFLUENT CONTROL

In many NP or NPK slurry process granulation plants, it is normal to operate a closed water system with no liquid effluent and with very low NH_3 and fluorine emissions.

Figure 5 is a simplified flowsheet for the scrubbing system normally part of a modern slurry process granulation plant. The availability of part or all of the phosphoric acid feed for scrubbing makes possible very high mole ratio products and maximum incorporation of ammoniacal nitrogen in the formula. The first stage of scrubbing utilises venturi cyclonic scrubbers, usually with wetted elbows. Tailgas scrubbing may be done in sprayed void towers one or more stages, or using packed bed in towers. The latter has the advantages of making possible more transfer units but the design has to be done carefully to avoid scaling and frequent cleaning.

By proper control of the mole ratio of the scrubbing solution both F and NH_3 emissions to the tailgas scrubber can be limited. Recirculated fresh water is used in the tailgas scrubber, normally with pH control using a small amount of phosphoric acid. pH control improves overall NH_3 recovery without excessive fluorine emission. A bleed out of tailgas scrubber solution is advanced to the primary scrubbers. The effect of this dilution is the requirement of slightly higher phosphoric acid composite strengths. However, even with tailgas scrubbing the normal range of acid strength is from 42% to 48% P_2O_5.

The present environmental sensitivity makes it undesirable to discharge opaque emissions to the atmosphere. Fume, submicron particulate, is frequently formed in granulators where H_2SO_4 at 93% is allowed to contact urea, ammonium nitrate, gaseous or liquid ammonia, particularly in the presence of chloride. Most modern slurry process plants maintain the heat required for granulation by ammoniation of phosphoric acid to DAP and not by the use of sulphuric acid in the granulator.

Many slurry process NP or NPK plants based on DAP formulae are in operation without tailgas scrubbing, achieving very low particulate or dust emissions. Particulate emissions with tailgas scrubbing are virtually nil.

For installations in Florida, fluroine emission is limited to maximum 0.06 lb per ton of P_2O_5. Many plants there are able to utilise their acidified cooling pond water which is used to cool the gases and reduce the fluorine content prior to tailgas scrubbing with recycled fresh water. This, however, is not practical with the chlorides present in NPK fertiliser scrubbing.

Ammonia emissions have received increased attention due particularly to the rising costs of nitrogen. Depending on the extent of tailgas scrubbing and the economics of a particular case, recoveries of ammonia feed of 98% to above 99.5% are practical. At least one DAP plant is monitoring NH_3 emissions from the granulator and preneutraliser with continuous, recorded NH_3 analysis. This serves to warn of problems at their onset and to give management a tool for process improvement and operation evaluation.

Measurable losses of P_2O_5 and K_2O were recorded at less than 0.1% each in a recent test run of 12:32:16 in India. In addition, fugitive P_2O_5 losses occurring with dusty, fluffy materials like run of pile TSP, normal super or powdered MAP are virtually nil in a slurry process plant using phosphoric acid.

VI MECHANICAL AND PLANT ARRANGEMENT IMPROVEMENTS IN SLURRY PROCESS PLANTS

Innovations in plant arrangement and in the unit operations involved in slurry process plants continue. We would like to describe here some of the recent slurry process improvements.

1. Aging Belt Flowsheet

The Dorrco slurry process granular fertiliser plant can be built in several configurations, depending on the process requirements. The most recently developed arrangement is shown on Figure 6. In this arrangement, the key feature is a slowspeed conveyor belt, which allows the granulator discharge surface to dry, prior to introduction to the dryer. Three such lines producing TSP and DAP are in operation in Florida. The concept was first used to our knowledge in the plant of Supra at Landskrona, Sweden where it has been processing very successfully MAP and ammonium nitrate based NP and NPK grades since 1966.

Enough evaporation and absorption of moisture takes place on the aging belt to reduce substantially dryer feed chute and front end scaling especially for sticky materials such as slurry process TSP, ammonium nitrate grades, MAP grades and DAP. Chute rodding, normally an onerous task, especially for slurry TSP, is virtually eliminated; the need for knockers and chains in the front end is greatly reduced. Also the arrangement results in a very short conveyor for recycle fines which greatly reduces maintenance.

One major advantage for the plant is the concentration of the major equipment in one high portion. For TSP and DAP plants in moderate or dry climate areas, the dryer may be partly outside of the building or covered by a minimum canopy type shelter. The size of the building can be minimised, and construction of the major structure can proceed before erection of the dryer.

2. Screening and Recycle Control

The latest Jacobs-Dorrco slurry process design incorporates improved screening and recycle control. The screening configuration is shown in Figure 6. However, the screening arrangement described here can be used in any slurry process granulation plant, not just a plant with an aging belt. For even very large capacities only two screen lines are required so that a screen feed conveyor or multiple splits are usually not required.

a) Single Deck Oversize Screens

Since for single deck screens the oversize screen area is no longer dependent on the product screen as is the case for double deck screens, the area required for the single oversize screens is considerably smaller. Improved bypass arrangements are used for bypassing screens and/or pulverisers during cleaning.

b) More Efficient Product Screening

The product screening also uses single deck screens, again for maintenance and performance advantages. However, we wish to emphasise that product screening efficiency is greatly improved in an arrangement in which the product take-out feeders are used to feed the product screens. Therefore, only the amount of feed required to give the desired product rate is screened. This ensures maximum screen efficiency.

c) Recycle Control

Automatic reycle control is incorporated in the design whereby the product take-out feeders (product screen feeders) are controlled by the load in the primary elevators as measured by recording the amperage or wattage or by a recycle weigh scale, preferably of the nuclear type located at an appropriate spot.

The calibration of the product screen feeders which may be a variable speed weigh belt gives the operator a running screen analysis of the fine fraction of the recycle. Conceivably this signal can be incorporated into automatic process control.

d) Product Polishing Screen

A second stage of product screening (polishing) may be provided, where almost all fines and oversize are removed to ensure a very closely sized product. A set of typical screen analyses produced in a commercial DAP plant using a single deck (fines) polishing screen but with double deck primary screens is given in Figure 7. We believe the first polishing screen was incorporated in the Dorrco designed granulation plant at Donaldsonville, La., now operated by Agrico. Polishing screens (single or double deck) have now become standard to most slurry process granulation plants.

The combination of single deck screens, the Jacobs-Dorrco product screen feed control feature and the polishing screen means that less overall area for product screening is required to make a closer sized product than previously possible.

3. Granulator Design Details

Over the years several major problems have plagued rotary drum granulators in spite of the advantages they have in terms of evaporative capacity and ammoniation efficiency. In general, coping with scale and lumps has been a major problem as well as getting good slurry distribution.

Granulating drums in most recent slurry process plants use a loose rubber lining which is attached as panels. Figure 8 shows the bolts attaching the lining in a Dorrco drum granulator. The rubber is of special specification to have proper elasticity and long life. This type of lining has generally replaced mechanical or stationary scrapers. In one Dorrco plant in operation since 1968 the lining has been replaced twice.

Other recent modifications have included strategically placed inflatable panels to eliminate build-up on the sparger and spray pipe support, better ventilation and a grizzly for handling lumps. Slurry distribution is usually by one or two large nozzles which remain open for extended periods. The slurry is now almost universally pumped rather than overflowing from the preneutraliser as in some early plants.

For processes such as slurry TSP where a great excess of slurry is available, and where no ammoniation is practiced, removal of the downstream dam in the granulator has made possible handling of granulator products as wet as those normally discharged from blungers.

While many operators still feel that blungers are easier to operate, the capacity advantage especially for high liquid phase grades indicates to us a continued trend toward the granulating drum.

4. Grinding of Oversize

The screen feed particle size analysis listed in Figure 7 shows a substantial quantity of oversize material. In the Jacobs-Dorrco slurry process no attempt is made to do a highly efficient grinding job on the oversize. An equilibrium of oversize particles in the recirculation is achieved. Oversize mills, chain mill type, are relatively open and require infrequent attention compared to earlier mills. In addition, the mill may utilise a special rubber lining to reduce buildup and scaling.

Large lumps, plus 37.5 mm or 50 mm, which can be formed, particularly in the granulator, are autogenously ground to pass a rotary bar grizzly built in the discharge end of the dryer. This eliminates various types of lump crushers previously attempted and which, in our experience, were not particularly successful.

In addition, while on the subject of lumps of fertiliser, it is good practice to provide a means for crushing and returning these to the recycle system. If these materials resulting from spills or cleanups, cannot be returned via the solids raw materials reclaim and feed system, then we usually recommend a special lump reclaim handling system where payloader cleanup can be used.

VII FUTURE TRENDS

The slurry process for granular fertiliser will continue to be the dominant factor, we believe, in new large fertiliser plant construction. We also see the following trends:

1. A trend to large capacity single line plants, utilising dryers in the 4 to 5 meter diameter range.
2. A trend to utilisation of the various techniques available for reducing recycle ratio in slurry process granulating plants, particularly where the practice has been to operate at above 5:1 recycle to product ratio.
3. A trend to wider acceptance of various forms of bulk blending as a means to higher productivity in the production of fertilisers.

We would like to dwell a little bit on the latter point. In 1975 the breakdown of fertiliser materials used in the U.S.A. was as follows:

Direct application materials	-	30%
Bulk blend materials	-	35%
Fluid Mixtures	-	15%
Granulated NPK materials	-	20%

Slurry process DAP and TSP were used in both bulk blends and in the direct application classification. Of the potash used in the U.S.A., 24% was consumed as granular in bulk blends. In addition some coarse potash was used in bulk blends because granular potash is in short supply.

We believe the practice of bulk blending will move into other areas of the world to a greater extent in the future. We see some movement in the U.K., for instance. Since granular potash may not be available in all circumstances, it would make sense to produce grades with varying ratios of P_2O_5 to K_2O such as 14:36:12, 10:30:20, 10:26:26 and 8:20:30 at a large central plant. In addition, of course, granular MAP, DAP to TSP could be produce in the same plant. These materials would then be shipped to local bulk blending plants to be combined with granular or prilled urea or ammonium nitrate locally and according to local soil analyses.

The plan would have several advantages. First, the production of the NPK grades like these, which contain 5% or less urea or ammonium nitrate could be accomplished at very high capacities per single line. Production rates of 125 MTPH are feasible in equipment presently in use in Jacobs-Dorrco slurry process plants.

Second, storage and handling of these grades, and granular MAP or DAP can be done under normal fertiliser storage conditions.

Third, this plan offers a viable alternative to the manufacture of non granular MAP at a central plant, with granulation to NPK fertiliser at satellite facilities. The basic disadvantages of MAP handling and transport are given by Mr. S. Jacob of IFFCO in Reference (6). Mr. Jacob, after receiving about 30,000 tons of non granular MAP for the plant at Kandla, India, discusses the caking, bulk density and windage loss problems about which little has been described. Those of us who are familiar with handling ROP, TSP or normal super know that the handling losses of this type of material can be relatively high. It seems to use that attempting to ship non granular phosphate materials is a step backward.

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(3) "Operational Experiences in NP-NPK Granulations at MFL" By P.N. Arunachalam and V.R.R. Gupta, FAI-ISMA Seminar 1975, New Delhi, India.

(4) "Production of Urea-DAP" Fertilisers by the Dorr-Oliver Slurry Process" By R.L. Kulp, E.R. Landgraf and D.W. Leyshon, A.C.S., August 1973, Chicago, Illinois.

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(6) "Granulated NP/NPK Fertilisers" By Sebastian Jacob, FAI-ISMA Seminar, 1975, New Delhi, India.

(7) "Plant Production of 18:46:0 Using Non-Granular Monoammonium Phosphate" By T.C. Kearns, A.C.A., August 1973, Chicago, Illinois.

(8) "Some Developments Aimed at Reducing the Recycle Ratios of High Analysis NPK Fertiliser Process" By J.L. Hawksley and G. Hunter, FAI-ISMA Seminar 1975, New Delhi, India.

(9) "Production of Monoammonium Phosphate in a Pipe-Cross Reactor" By F.P. Achorn, The Fertiliser Industry Round Table, November 1975, Washington D.C.

TABLE 1

SLURRY PROCESS GRANULATION PLANTS

RECENT INSTALLATIONS - DORRCO PROCESS

Plant	Location	Year in Operation	Grades	Key Ingredients
Madras Fertilisers (Third Line)	India	1976	17-17-17 14-28-14 24-24-0	Prilled Urea
Texasgulf Inc.	North Carolina	1976	TSP	
CF Ind. (3 Lines)	Florida	1974	DAP TSP	
Polimex (2 Lines)	Poland	1974	8-24-24	
IFFCO (2 Lines)	India	1974	10-26-26 12-32-16	Minor amounts of Urea
IVP	Venezuela	1974	DAP	
Technoimport	Bulgaria	1974	TSP	
Madras Fert. (2 Lines)	India	1972	17-17-17 14-28-14 24-24-0	Prilled Urea
Polimex (2 Lines)	Poland	1970	DAP	
Zorka Sabac	Yugoslavia	1970	DAP 17-17-17 10-20-20 0-25-25	Ammonium Nitrate
Polimex (2 Lines)	Poland	1969	TSP	
Toyo Koatsu	Japan	1968	16-16-16 13-20-15 10-15-25 12-24-12	Urea n-superphosphate, Sul-Po Mg, Phos. Acid, MgO, Trace Elements
Shellstar	England	1968	17-17-17 15-15-23 23-11-11 21-14-14 23-10-11	Ammonium Nitrate

Plant	Location	Year in Operation	Grades	Key Ingredients
Agrico (Formerly Gulf Oil) (2 Lines)	Louisiana	1967	DAP 18-22-0	
W.R. Grace	Florida	1967	DAP 13-52	
Supra	Sweden	1966	25-20-0 20-11-11 8-15-25/ 2 Mg 11-11-22 10-20-20	Ammonium Nitrate
Occidental (2 Lines)	Florida	1966	DAP TSP	
C.I.C.	Rumania	1966	DAP 23-23-0 13-26-13	Ammonium Nitrate
Sherritt Gordon	Canada	1965	23-23-0 16-20 11-48	Urea
Satec	France	1965	TSP DAP 10-20-20 10-30-20	
Carbochimique	Belgium	1963	12-21-23 17-17-17 13-13-27 18-13-10	Ammonium Nitrate
Nitto	Japan	1962	17-17-17 20-10-20 16-20-16	Urea

TABLE 2
JACOBS-DORRCO SLURRY PROCESS
17-17-17

Product Characteristics

Grade – 17-17-17 (± 0.5 variation maximum for each nutrient)
Particle Size – 95% between 1.5 and 4.0 min.
Hardness – 1.45 Kg
CRH – 55%
pH (20:1) – 7.65 (TVA – granulator)
7.20 (blunger)

Operating Requirements

Power	30 KWH/Ton of Product
Fuel	10 Kg fuel oil/Ton of Product
Steam	20 Kg/Ton of Product
Process Water	Negligible
Effluent	Nil
Recycle Rate	3.0:1.0

DRYING RATE CURVES
JACOBS-DORRCO DATA FOR 1:1:1 GRADES
USING AMMONIUM NITRATE OR UREA

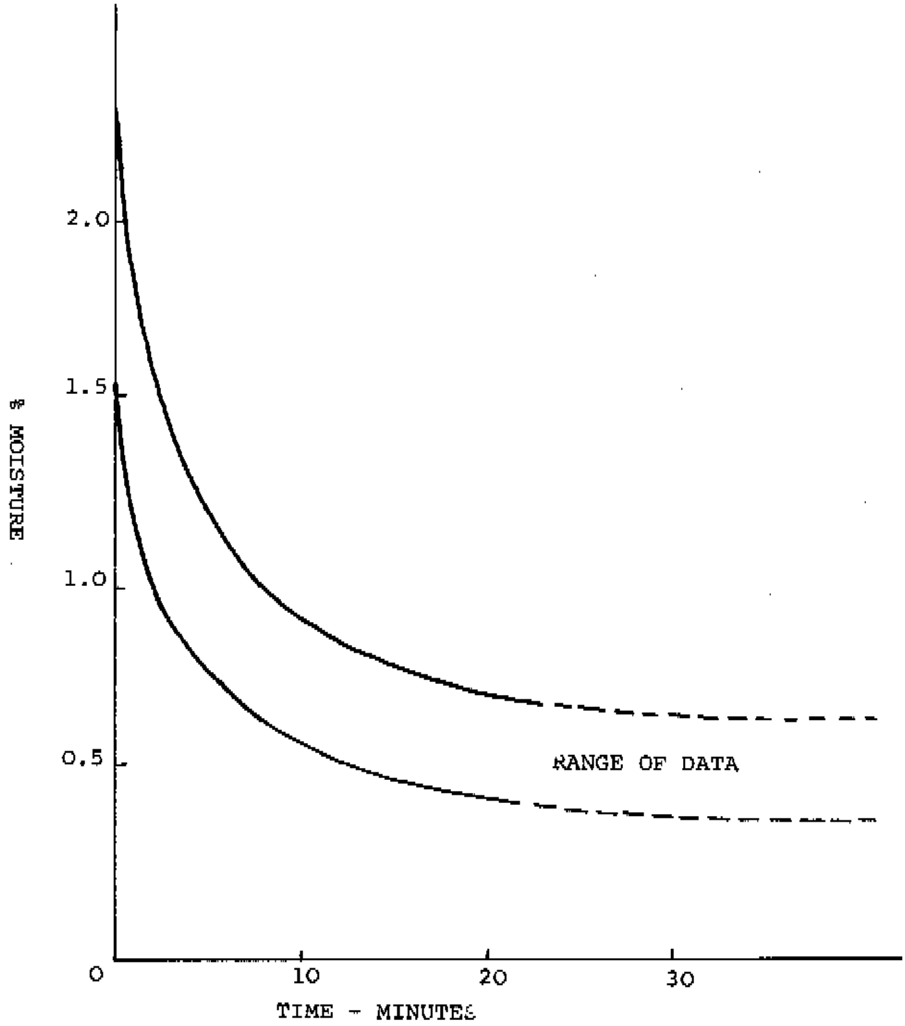
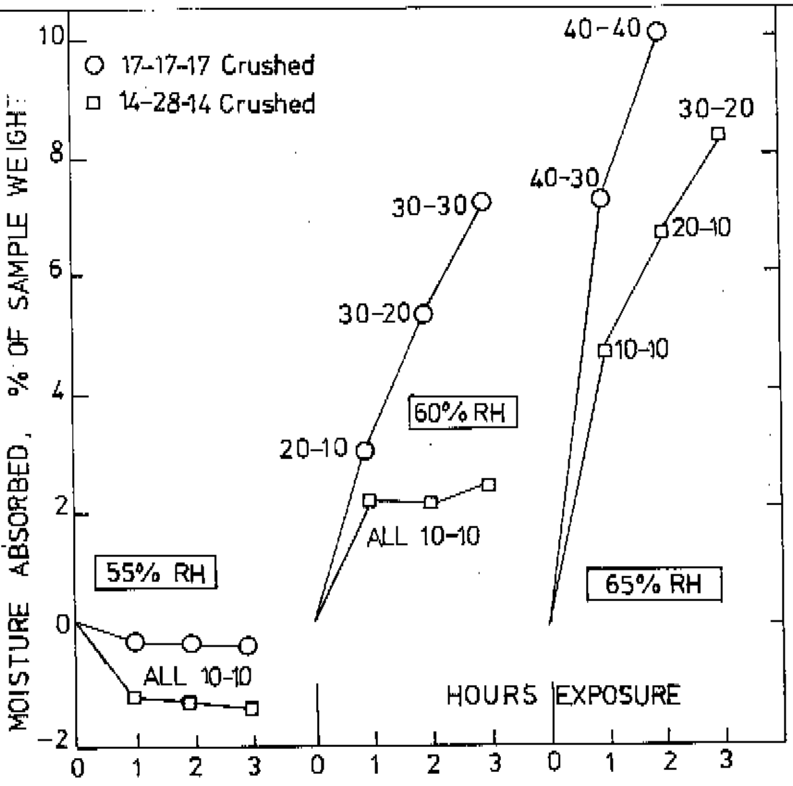


FIGURE 1

Note: The two rating numbers separated by a dash indicate physical condition. The first represents the appearance before touching with the finger and the second represents the condition after touching with the finger. The rating scales are as follows:

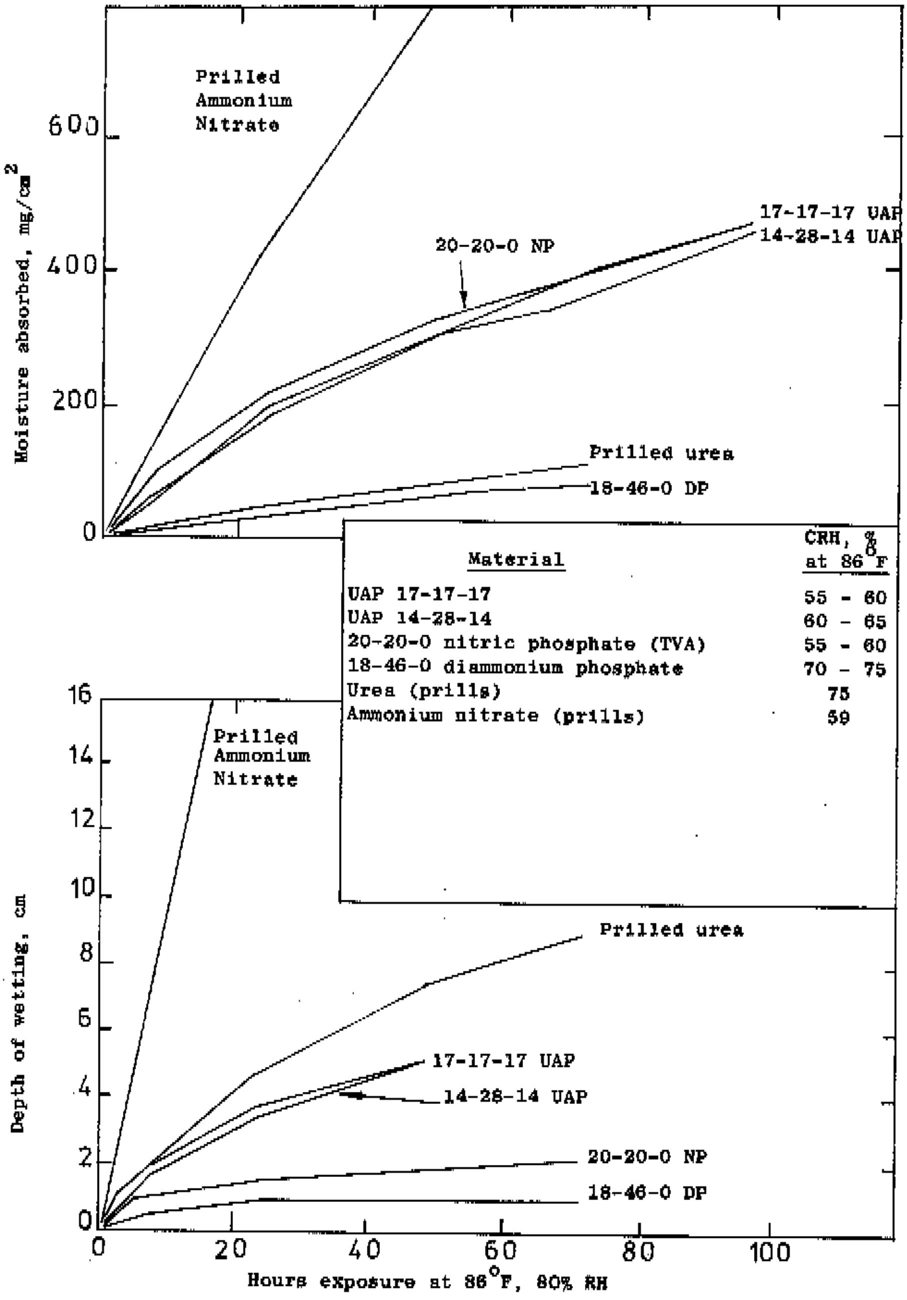
First Number (Appearance)		Second Number (Condition)	
10	Perfectly free flowing, dry.	10	No agglomeration under finger pressure.
20	Part free flowing; part agglomerated; no moisture visible.	20	Loose agglomeration under finger pressure; is easily disintegrated with finger.
30	All agglomerated; no moisture visible.	30	Agglomeration under finger pressure; is difficultly disintegrated with finger.
40	Moisture visible on particles.	40	Forms mud under finger pressure.
50	Liquid	50	Is liquid before finger pressure.



Moisture Absorption Data Obtained in Critical Relative Humidity Tests of Urea-Ammonium Phosphates from a Commercial Plant

FIGURE 2

From TVA May 1972 Report



Material	CRH, % at 86°F
UAP 17-17-17	55 - 60
UAP 14-28-14	60 - 65
20-20-0 nitric phosphate (TVA)	55 - 60
18-46-0 diammonium phosphate	70 - 75
Urea (prills)	75
Ammonium nitrate (prills)	59

Moisture Absorption and Penetration of Fertilisers

FIGURE 3

From TVA May 1972 Report

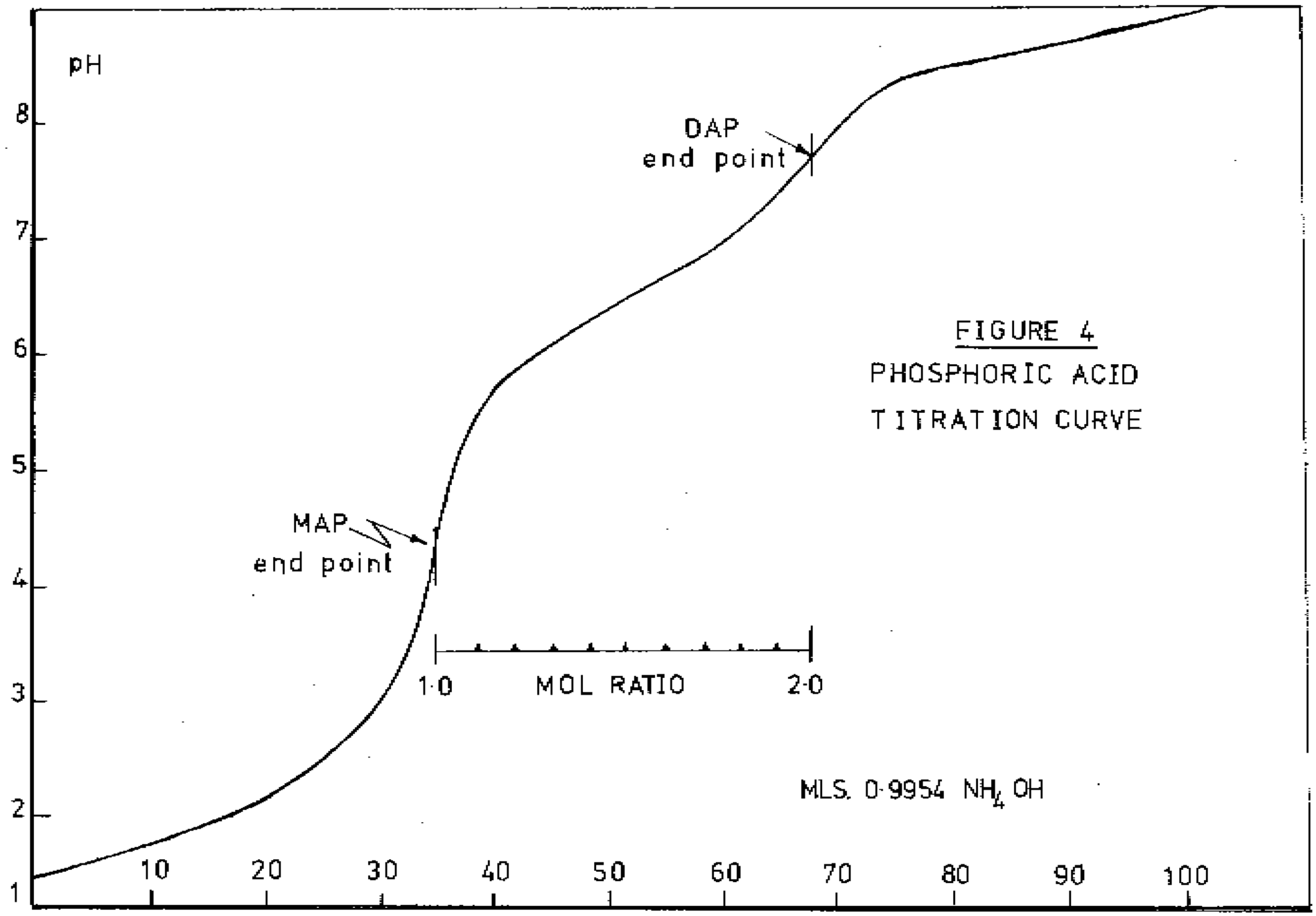


FIGURE 4

PHOSPHORIC ACID

TITRATION CURVE

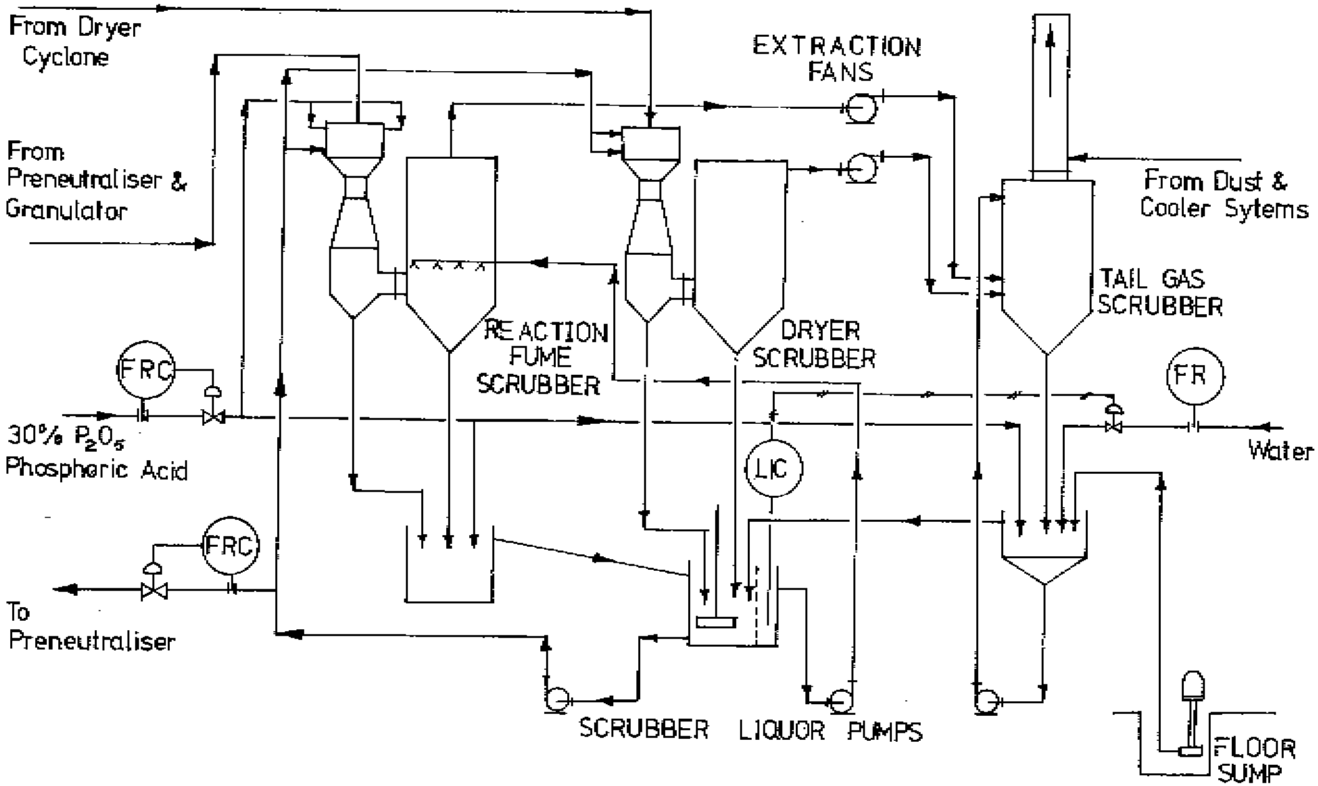
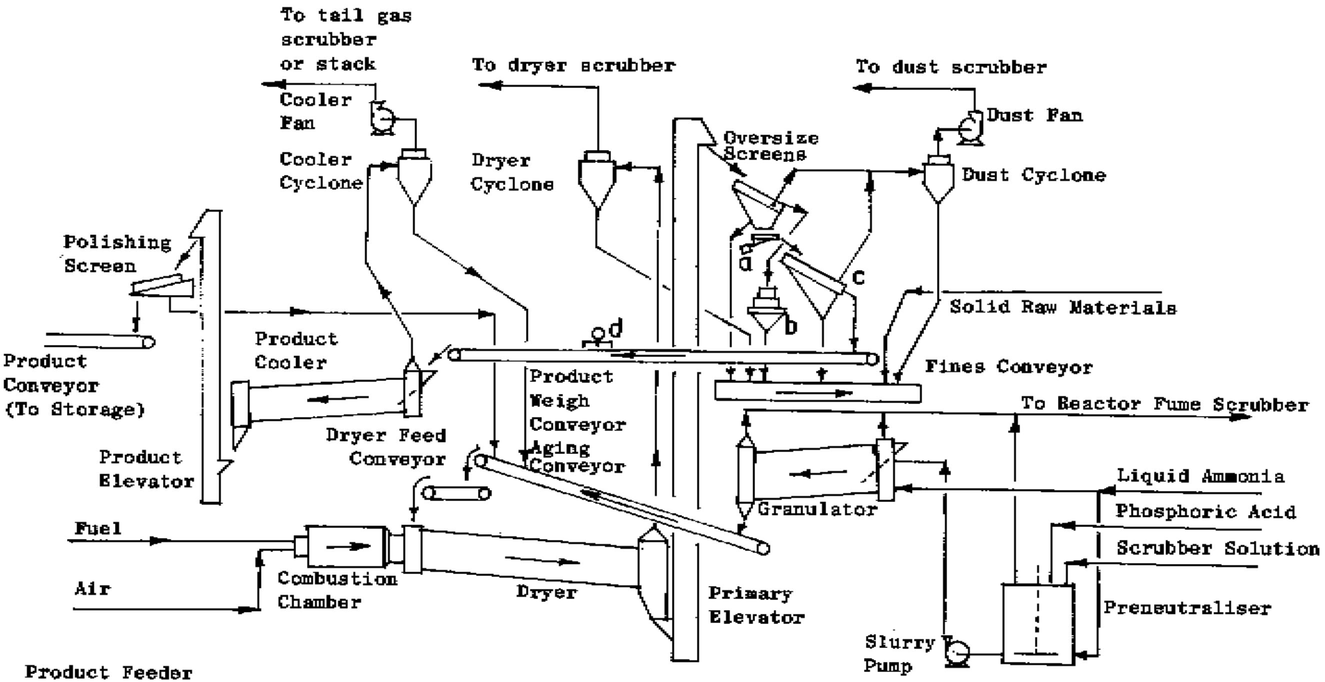


FIGURE 5

SLURRY PROCESS SCRUBBING SYSTEM

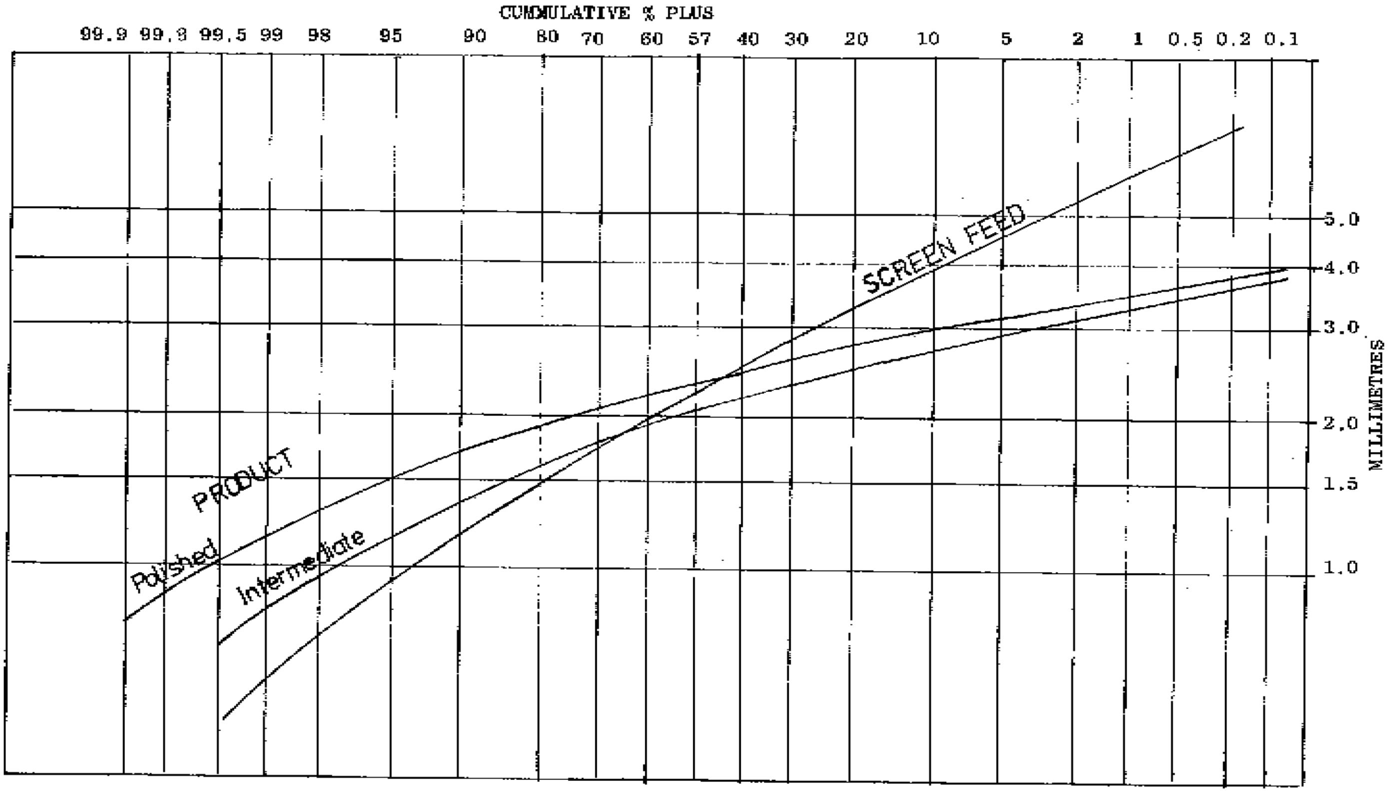
ISM
6/76



a. Product Feeder
b. Oversize Pulveriser
c. Product Screen
d. Product Scale

BASIC FLOWSHEET

FIGURE 6



TYPICAL SLURRY PROCESS DAP SCREEN ANALYSES

Single Deck (Fines) Polishing Screen

FIGURE 7

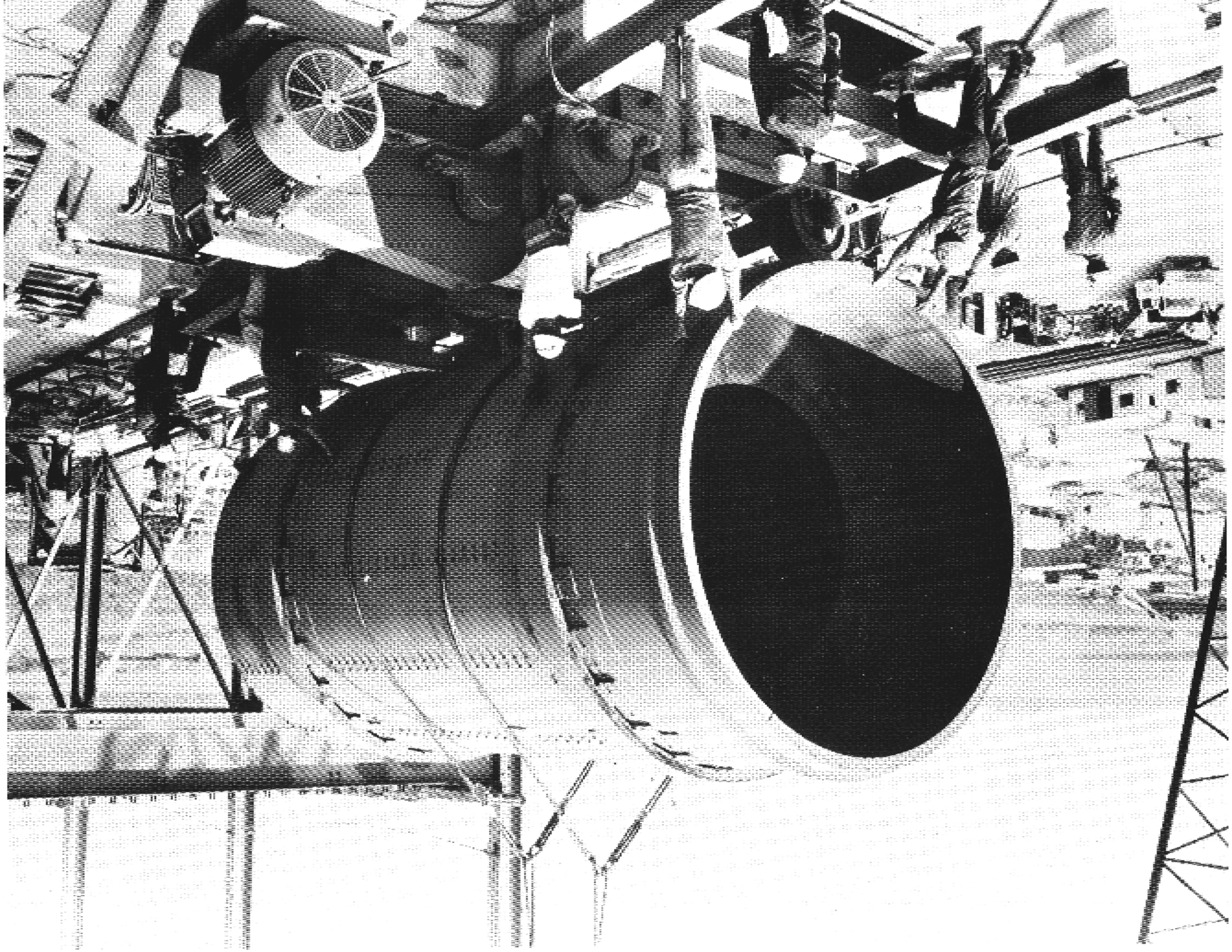


FIGURE 8

12 ft. diameter by 24ft long TVA Ammoniator Granulator
Being installed in a Dorrco Slurry Process Plant