

IFA Technical Conference

**Beijing, China
20-23 April 2004**

FLWSHEET OPTIONS FOR THE PRODUCTION OF UREA BASED NPK FERTILIZERS

D M Ivell,
Jacobs Engineering, USA

INTRODUCTION

Designing a plant for the production of high analysis urea-based NPK fertilizers presents a number of challenges that differentiate this type of plant from, for example, an MAP/DAP plant. Most of the problems are associated with the high solubility and hygroscopicity of these mixtures.

This paper discusses the differences in the flowsheets required, including equipment types, to overcome the inherent processing difficulties that can be encountered when producing NPK fertilizers containing high levels of urea. The paper focuses on high analysis fertilizers only. Raw materials such as ammonium sulfate or superphosphates are not considered.

The paper also discusses the applicability of the use of solid ammonium phosphate versus phosphoric acid and urea melt versus urea in the solid form.

1. PHYSICAL PROPERTIES OF UREA BASED NPK FERTILIZERS

The following table shows the solubility of various fertilizer salts commonly used in the manufacture of urea based NPK fertilizers:

Table 1 Raw Material Solubilities (g/100g solution)

	25°C	50°C	75°C	100°C
Urea	55	67	79	88
MAP	30	41	52	63
DAP	42	48	53	59
Potash	26	30	33	36

Note that the solubility of all materials rises with increasing temperature and that urea is by far the most soluble raw material. One last point that should be made is that a mixture of urea and potash is very much more soluble than either urea or potash. For example, 18-18-18 has a solubility of about 90 grams per 100 grams of solution.

Received 14 January 2004 for presentation at the 2004 IFA Technical Conference, 20-23 April, Beijing, China

E-mail: David.Ivell@jacobs.com

In order for a mixture to granulate it requires a certain amount of liquid phase – normally about 15%. This liquid phase is provided by part of the mixture dissolving in water present in the granulator. Most of this water is provided with the raw materials. As solubility increases with temperature, it follows that less water is required to dissolve a certain amount of the mixture and thus less water is required for granulation.

Therefore:

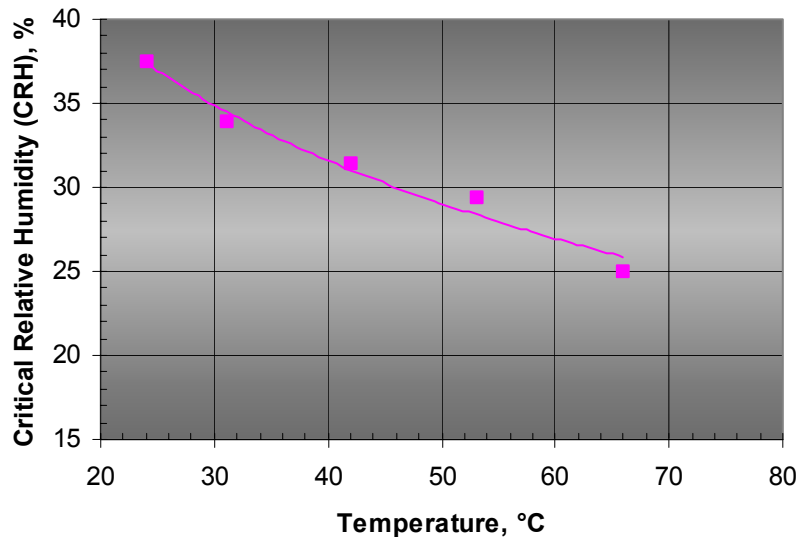
- Moisture required for granulation is very low. Water input to the granulator must be minimized. The use of a pipe reactor and/or the use of solid ammonium phosphate can help in this respect.
- The temperature of the granulator discharge material has to be limited to avoid granulation moisture requirements being so low that uncontrollable over-granulation results. In practice, granulation temperature needs to be controlled at typically 75-80°C depending on grade
- Drying temperatures need to be much lower than for DAP/MAP and airflows need to be much larger. Typical dryer temperatures, depending on grade are 100-140°C at the inlet and 75-85°C at the outlet.
- The temperature rise of the solids in passing through the dryer has to be limited to prevent over-granulation occurring in the dryer. Typically the temperature rise through the dryer is in the range 0-3°C only.

The mixtures are also extremely hygroscopic with Critical Relative Humidity (CRH) often less than 40% at ambient temperatures. The CRH also falls rapidly as temperature increases such that drying rate can be affected unless sufficient dryer airflow is provided (and/or the air to the combustion chamber is dehumidified).

The following graph shows the CRH temperature relationship for 17-17-17 at a product moisture of 0.8%:

Flowsheets / Equipment Design

Critical Relative Humidity vs. Temperature



Granulation

Since, unlike MAP/DAP, the predominant method of granulation is agglomeration, longer rolling distances are used in the design of NPK granulators. When a pipe reactor is employed, evacuation of the reaction steam is of paramount importance. Since these mixtures have low CRH values, relatively large granulator airflows are required. These factors translate into larger diameter drums with a larger L/D ratio than is typically used for MAP/DAP plant designs.

Drying

As mentioned above, the airflow required per tonne of product for a urea based NPK plant is much higher than that required for an MAP/DAP plant. In addition, because drying temperatures have to be much lower than for MAP/DAP, longer residence times are necessary (typically in the range 15-20 minutes). Product moisture levels of less than 1.0% are required to prevent caking and give sufficient product hardness. All of this translates into a larger drying drum (diameter and length) coupled with either a lower slope or lower speed. Gas velocity through the dryer should be limited to under 4.0 m/s and preferably under 3.5 m/s to prevent excessive entrainment of dust. This is particularly important with urea based NPK grades as excessive urea in the scrubbing system leads to foaming problems.

Screening

The material discharging from the dryer is slightly sticky since dryer temperatures are controlled fairly close to the limit in order to get a reasonable drying rate. Therefore

the type of screens needs to be selected with care. Jacobs specify screens with a static frame where the screen cloth is vibrated. A “cleaning cycle” is specified which increases the level of vibration on a timer for a short period of time. These design features keep the screen cloths free from pegging.

Alternative screen types either with gyratory motion frames or with reciprocating frames have proved difficult to keep clean. The “bouncing balls” normally used in these type of screen have proved to be ineffective in the long run.

Oversize material is particularly sticky at the temperatures encountered at the dryer discharge, especially when crushed, as the inside of the granule has a higher level of moisture. Jacobs therefore recommend that oversize be cooled together with product. This allows the oversize granules to harden before crushing, which avoids crusher build up and poor crushing performance (generation of excessive dust).

In addition this combination – hot fines and cold oversize – optimizes the recycle temperature and allows granulation temperature to be controlled in the desired range of 75-80°C. The use of a pipe reactor, for example, together with a totally “hot” recycle typically results in granulator discharge temperatures well in excess of 80°C.

Cooling

Since oversize and product is being cooled, the use of a fluidized bed cooler is inappropriate due to the wide variation in fluidizing velocity requirements. Jacobs therefore specify rotary drum coolers. A rotary drum cooler has the added advantage of being less prone to product moisture pick up as the contact of the air with the solids is less intimate. In addition less airflow per tonne of throughput is required since a rotary drum is counter-current versus a fluidized bed cooler that is cross-flow. Standard practice is to chill the air using ammonia to minimize airflow requirements and use the ammonia gas generated within the process.

Coating

The only coating normally required for MAP/DAP is an oil that is primarily designed to reduce product dusting on subsequent handling. However, for urea based NPK coating is necessary as an anti-caking measure. The objective is to coat each granule with a barrier that prevents crystal bridges forming between adjacent granules.

Amine-oil mixtures have proved very effective with ammonium nitrate based products but are less so with urea based products. Jacobs therefore specify a combination dust and oil coating. Kaolin or talc is normally used. To be effective it has to be applied as a very fine powder (typically less than 50 microns). The oil is acting primarily as a “glue” to stick the dust to the granule surface. Typical application rates are dust at 1.0-1.5% and oil at 0.3-0.5%.

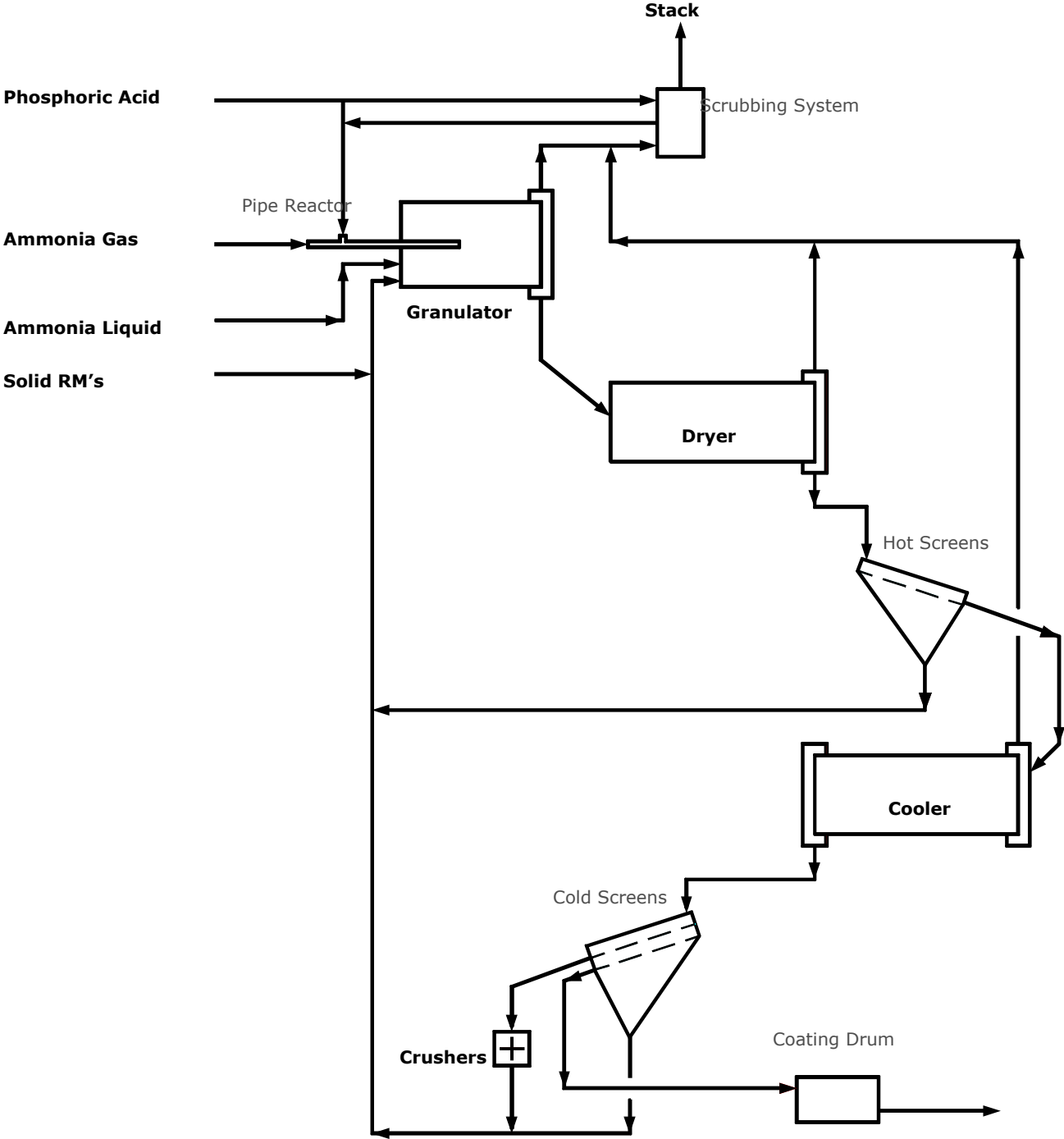
Conveyors

In view of the highly hygroscopic nature of the products it is advisable to keep the use of conveyors to the minimum. Optimization of the layout of the equipment can enable chutes to be used in lieu of conveyors, which helps reduce potential spillage points and minimizes contact of ambient air with the solids.

Crushers

The most robust and reliable type of crusher has been found to be double opposed chain mills. Although theoretically roll crushers should give superior process performance, practical experience has shown that not only is the process performance poor but also reliability of the machines is poor and maintenance costs are high.

A typical simplified flowsheet is shown below:



2. RAW MATERIAL OPTIONS

The principle options are as follows:

- Urea as a solid or a melt/solution
- Ammonium phosphate as a solid or produced "in-situ" from reaction of phosphoric acid and ammonia.

2.1 Urea

Urea can be supplied either in the solid form (prills or granules) or in the form of a concentrated solution (95%). The advantage of using a solution rather than prills or granules is that the urea is distributed more evenly within each granule. This results in harder granules with no visible urea present. The disadvantage is that the increase in liquid phase increases very significantly. This means that in situations where the ammonium phosphate is produced "in-situ", either by a pipe reactor or a conventional preneutralizer, the use of a urea solution will result in a fairly significant reduction in capacity for a fixed size of plant. This combination is therefore not recommended.

However in situations where a solid form of ammonium phosphate is being used, a urea solution can be employed for at least part of the urea feed.

If urea is used in the solid form prills are generally preferred to granules due to their smaller size. Prills are also normally available at a lower price than granules. If prills are not available however Jacobs would recommend that a crusher be installed so that the urea can be better incorporated within the product granule.

2.2 Ammonium Phosphate

When phosphoric acid is produced at the site, normal practice would be to produce ammonium phosphate "in-situ" using either a pipe reactor or preneutralizer or a combination of the two.

However on sites with no direct access to phosphoric acid and/or inland sites where the transport of phosphoric acid to the site is a significant added cost, it may be interesting to use ammonium phosphate in the solid form. If all the ammonium phosphate is supplied in the solid form, the use of urea solution makes a lot of sense.

The problem with such a flowsheet is that although there is very little ammonia to be recovered, dust entrained in the various process airstreams must still be recovered. Because of the highly soluble nature of the NPK mixture the water balance is critical and finding a home for the water used in the scrubber system is a challenge. The only way in which the scrubber water can be recycled to the process is to use it in the preparation of the urea solution. With this process route, in order to minimize the amount of water required for scrubbing, a baghouse would normally be used on the cooler exhaust and this air recycled to the dryer as quench air. Special precautions need to be taken to ensure that the dust collected on the filter bags does not pick up moisture, especially during shutdowns.

A third alternate would allow an acid based scrubbing system but with partial replacement of phosphoric acid and ammonia with solid ammonium phosphate.

In summary there are basically three formulation routes that can be used as follows:

	Formulation No. 1	Formulation No. 2	Formulation No. 3
Urea Prills	Yes	Yes ¹	Yes
Urea Soln	No	Yes ¹	No
Phosphoric Acid	Yes	No	Yes ³
Ammonia	Yes	No	Yes ³
MAP	No	Yes ²	Yes ^{2,3}
DAP	No	Yes ²	Yes ^{2,3}
Potash	No	Yes	Yes

¹ The ratio between urea prills and solution can be varied depending on the grade of NPK being manufactured.

² MAP and DAP can be used in combination or as alternates.

³ The ratio between phosphoric acid and ammonia and MAP/DAP can be varied depending on the grade of NPK being manufactured.