CHAPTER I

INTRODUCTION

1.1 Introduction to the NP/NPK rotary drum granulated fertilizer

1.1.1 Overview of the world NP/NPK rotary drum granulated fertilizer

During the past 40 years, fertilizer technology and production have greatly evolved. Fertilizers have changed in their physical characteristics such as density and obtainable levels of concentration, leading to better applicability to fit several purposes of use and less disposal waste. In 1950, there were not any granular fertilizers. Ten years later, 60 percent of all mixed fertilizers were marketed in the form of granules or pellets. Nowadays, modern fertilizers are mostly shaped into granules or pellets.

Granular or pellet shapes are less likely to cake than powdered materials, which would become dusts and corrosive. The uniformity of particle-size distribution, which could be earned with the granulation technique, is essential for various applications. In some cases, coatings are applied onto the fertilizer pellets that regulate and slow down the release rate of contents, but this has been used mainly for home gardening. The rotary ammoniator, the granulator recently developed, has been used in many mixed fertilizer plants, producing solid fertilizer in the granular form. Figure 1.1 shows a modern fertilizer plant with a pipe reactor and a drum granulator. Inside the pipe reactor, anhydrous ammonia, phosphoric acid and water are injected in various proportions. Then, the steam and fertilizer mixture is discharged directly into the granulator. The particle size distribution of the raw materials also affects the size of the granule fertilizer. Granules leaving the granulation drum are dried with the heat of reaction from the pipe reactor, and then screened to classify the product sizes. Since the product specifications must be met, e.g. particle size between 2 mm and 4 mm, oversize granules are subject to further crushing before returning to the granulator along with undersize granules for re-processing.

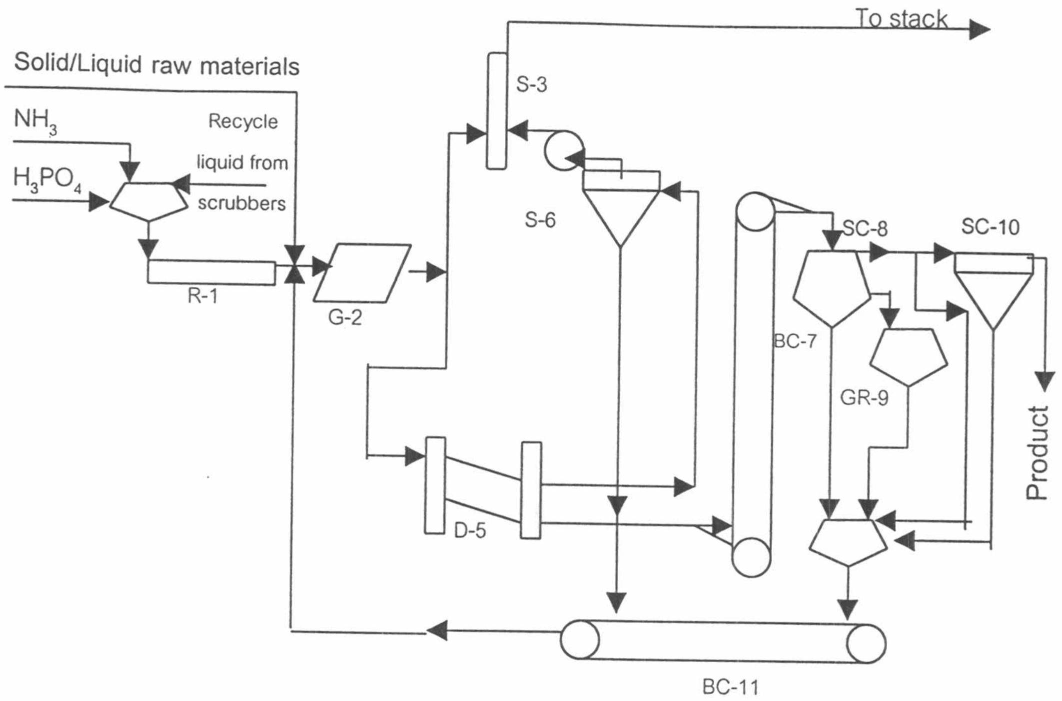


Figure (1.1) DAP/NPK process

Legend :

R-1	Pipe reactor	BC-7	Bunker elevator
G-2	Granulator	SC-8	Primary screen
S-3	Scrubber	GR-9	Crusher
D-5	Dryer	SC-10	Final screen
S-6	Cyclone	BC-11	Belt conveyor

1.1.2 Overview of the world NP/NPK rotary drum granulation mechanism

The concepts used in granulation have a pronounced impact on the design and operation of the granulation process equipment. Therefore, good understanding of the primary mechanisms of granulation, growth, and consolidation is essential in speculating the design features of the granulation process. The following is a brief description of the two major granulation mechanisms encountered in most fertilizer granulation processes.

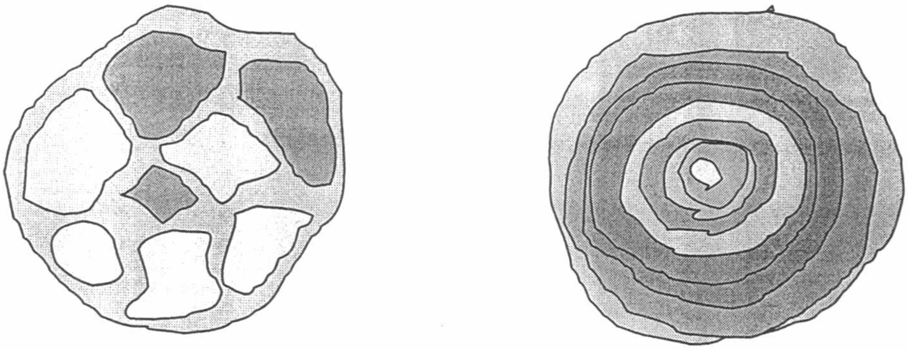
Agglomeration-type process

In most granular NPK productions, agglomeration is the principal mechanism responsible for initialization of the granulation process and subsequent growth (Figure 1.2). With regard to general agglomeration-type NPK formulations, 50%-75% of the raw materials are fed as "dry" solids.

These solid particles are collected and merged into agglomerates (granules) by mechanical interlocking and cementing – similar to the way a stonemason fashions a stone wall by using stones of various sizes and shapes, and mortar as the cementing agent. The cementing agent for fertilizer granules is derived from salt solutions, for example, ammonium phosphate slurry and/or the dissolved salts on the moist surface of the soluble solid particles. The size, shape, surface texture, strength, and solubility of the solid particles may be varied broadly and have a profound influence on the granulation characteristics of the mixture.

Accretion-type processes

Accretion refers to the process in which one layer of a fluid material (for example, an ammonium phosphate slurry) after another is applied to a solid particle, causing it to grow in size. The slurry-type granulation processes used to produce DAP, MAP, TSP, and some nitrophosphate compounds are examples of accretion-type granulation processes. The accretion process is quite different from the agglomeration process with respect to the mechanism of granule formation and growth. As a result, the required process parameters for optimum operation of these slurry-type accretion granulation processes often differ from those used in agglomeration processes. In the slurry-type granulation process, a relatively thin film of moist slurry, or a nearly anhydrous melt, is repeatedly applied, dried, and hardened to form a relatively firm substrate consisting of granules that are exactly or approximately the size of the final product. In this process, layer by layer of the new material is applied onto the particle, giving the final granule an "onion-skin" structure (Figure 1.2). In fact, some agglomeration of particles also occurs, but this is not the predominant granulation mechanism.



Agglomeration

Accretion

Figure (1.2) Granule structure created by agglomeration and accretion

In this work, the agglomeration-type process is selected. Physical and chemical properties are, therefore, affected by these following factors:

1.1.2.1 Raw material particle size and surface characteristics

Because much of the initial (in-process) and final mechanical strength of the agglomerated NPK granule is obtained via the mechanical interlocking or fitting of individual particles, the mechanism in which the particle size, size distribution and surface characteristics of the solid raw materials are significant parameters. If the final product is in the size range of 2-4 mm, then the raw materials should be deviated only within a range of about 0.2-3 mm. An example of the particle-size distribution of solid materials ready to use in agglomeration-type NPK granulation plants without any need of further size reduction (crushing) is shown in Table (1.1)

Table (1.1) Typical particle-size distribution data for producing granular NPKs

Size (mm)	A/S	MAP	KCl	K_2SO_4	Urea(p)
-0.15	2%	10%	10%	0%	0%
0.15 - 0.30	23%	25%	55%	5%	0%
0.30 - 0.60	68%	35%	30%	20%	5%
0.60 - 1.00	6%	23%	5%	60%	3%
1.00 - 2.36	1%	6%	0%	15%	77%
+2.36	0%	1%	0%	0%	15%

1.1.2.2 Liquid phase (mass balance) and heat of chemical reaction (heat balance)

1.1.2.2.1 Liquid phase (mass balance)

Although mechanical interlocking of the particles within the granule structure must be optimized through selection and/or processing (crushing) of the raw materials (and sometimes recycled material), cementing is also needed to permanently bond the particles into strong agglomerates (granules). The liquid phase is derived from (1) soluble-salt solutions added to the granulator, for example, an ammonium phosphate slurry and/or a solution of urea or ammonium nitrate and (2) dissolution of the surface of soluble solid raw material and recycle particles. This dissolution is caused by the combination of heat and water contained in the above solutions or by steam or water fed to the granulator. Solubility data for some of the more common fertilizer salts are given in Table (1.2).

Liquid phase control is the key to achieving the desired level of granulation efficiency and product quality. Ideally, after drying, the liquid phase (salt solution) forms strong crystal bonds (salt bridges) among the particles of the agglomerate that are mechanically well-fitted and interlocked.

Table (1.2) Solubility of common fertilizer salts in water[a]

Fertilizer salt	Approximate concentration of saturated solution at indicated temperature (%)		
	0°C	20°C	100°C
Ammonium nitrate	54	66	90
Ammonium sulfate	41	43	51
Diammonium phosphate	30	41	58
Monoammonium phosphate	18	27	63
Potassium chloride	22	25	36
Potassium nitrate	12	24	71
Potassium sulfate	6	10	19
Urea	41	52	88

a. Values indicated are for pure salts.

1.1.2.2.2 Heat of chemical reaction (heat balance)

The quantities of liquid phase is also closely related to another criterion, i.e., the expected amount of heat created by various chemical reactions that occur during the granulation of a given NPK formulation. The amount of heat generated, particularly within the granulator, can have a marked effect on the solubility of the fertilizer materials and the amount of liquid phase formed and, therefore, the resulting granulation characteristics of the mixture. In general, to achieve optimum granulation, the calculated total liquid phase for a formulation, using the data in Table (1.3), should be lowered if the formulation produces a large amount of chemical heat of reaction in the granulator. However, the optimum relationship between liquid phase and heat of reaction for a specific formulation must be learned from actual operating experience.

Table (1.3) Liquid phase factors for selected materials frequently used in NPK granulation (agglomeration) formulas

Material	Liquid phase factor (kg/kg)
Anhydrous ammonia	0.50
Ammonia/ammonium nitrate solutions (various compositions)	1.00
Ammonium nitrate (prills)	0.30
Wet-process phosphoric acid	1.00
Sulfuric acid	1.00
Superphosphoric acid	1.00
Water or stream	2.00
Ammonium sulfate (crystalline)	0.10
Single superphosphate (run-of-pile)	0.10
Triple superphosphate (run-of-pile)	0.20
Potassium chloride (coarse or granular)	0.30
Potassium chloride (standard)	0.00
Diammonium phosphate (granular)	0.25
Monoammonium phosphate (nongranular)	0.20
Urea (prilled)	0.30

To obtain the total weight of the liquid phase in a formulation, multiply the weight of each raw material in the formula (kg) by the appropriate liquid phase factor. A total liquid phase weight value of about 300kg/tonne is considered optimal in many cases.

The most important heat-generating chemical reaction in most NPK granulation plants is the neutralization of acidic materials with ammonia inside the granulator. The approximate net amount of heat released when ammonia reacts with some common acids and other fertilizer materials is shown in Table (1.4). For the liquid phase, experience has shown that, if the amount of heat released in the granulator is about 45,000-50,000 kcal/ton of product (not including the recycle), the condition inside is generally considered favorable for optimum granulation. In fact, for the liquid phase, the proper level of heat is just another one of the many critical criteria that must be determined by experience and that must be met to obtain optimum granulation efficiency.

Table (1.4) Approximate net amount of heat released when ammonia reacts with various materials commonly used to produce granular NPKs

		Heat released (kcal/kg NH_3 reacted)	
Material reacted with ammonia	Reaction product (solid)	NH_3 gas	NH_3 liquid
Wet-process phosphoric acid (54% P_2O_5)	Monoammonium phosphate (MAP)	1,890	1,370
Wet-process phosphoric acid (54% P_2O_5)	Diammonium phosphate (DAP)	1,510	990
Monoammonium phosphate (MAP)	Diammonium phosphate (DAP)	1,130	610
Triple superphosphate (TSP)	Ammoniated TSP	1,580	1,060
Single superphosphate (SSP)	Ammoniated SSP	1,460	940
Sulfuric acid (100%)	Ammonium sulfate	2,165	1,645

1.1.3 Process description for ammonium sulfate synthesis in reactor of NP/NPK rotary drum granulated fertilizer

There are several advantages to modify the original ammonium phosphate reactor. First, ammonium phosphate-sulfate, the chemical reaction of ammonia gas with sulfuric acid in pipe cross reactor, leads to the capital cost reduction which is the first target of this study. Second, a group of fertilizers known as ammonium phosphate-sulfates has been popular for many years and is still popular in many areas. The most recognized grade is 16-20-0, which essentially consists of MAP and ammonium sulfate (AS). A reason for its popularity is that it is relatively non-hygroscopic. Last, ammonium phosphate-sulfate has some sulfur content, which is ergonomically useful for various crops and soils.

The typical process flow scheme for ammonium phosphate-sulfate synthesis in reactor of NP/NPK rotary drum granulated fertilizer involves the reactions of sulfuric and phosphoric acids with ammonia, illustrated in Figure (1.3). Most of the reactions of phosphoric and sulfuric acids with ammonia are carried out in a pipe, which discharges a melt into the drum granulator. Stream generated by the heat of reaction is swept out of the granulator by an air stream. An advantage of the process is that the heat of reaction is utilized to dry the product, and thus no dryer is necessary.

1.2 Objective of Thesis

To study the condition of the ammonium sulfate synthesis, effecting to both process yield and process capacity on industrial-scale production of fertilizer granules.

1.3 Scope of Work

1.3.1 The quantities of involved ammonium sulfate synthesis – the chemical reaction between ammonia gas (NH_3) and sulfuric acid (H_2SO_4) – are produced in pipe reactor to compensate solid ammonium sulfate imported raw material.

1.3.2 Process yield refers to the percentage of 2-4 mm., fertilizer granules sizing from rotary drum granulator requiring by market.

1.3.3 According to the restriction of heat control in process operation, depending on the heat of exothermic reaction of ammonium sulfate synthesis effects to capacity changing in process.

1.3.4 There is 6 fertilizer formulations (the 16-20-0, 16-16-8, 15-15-15, 13-13-21, 16-8-8, and 15-7-18) are drawn to study.

1.3.5 The study of effect of the ammonium sulfate thesis are conducted with design and analysis of experiment by regression analysis via SPSS program.

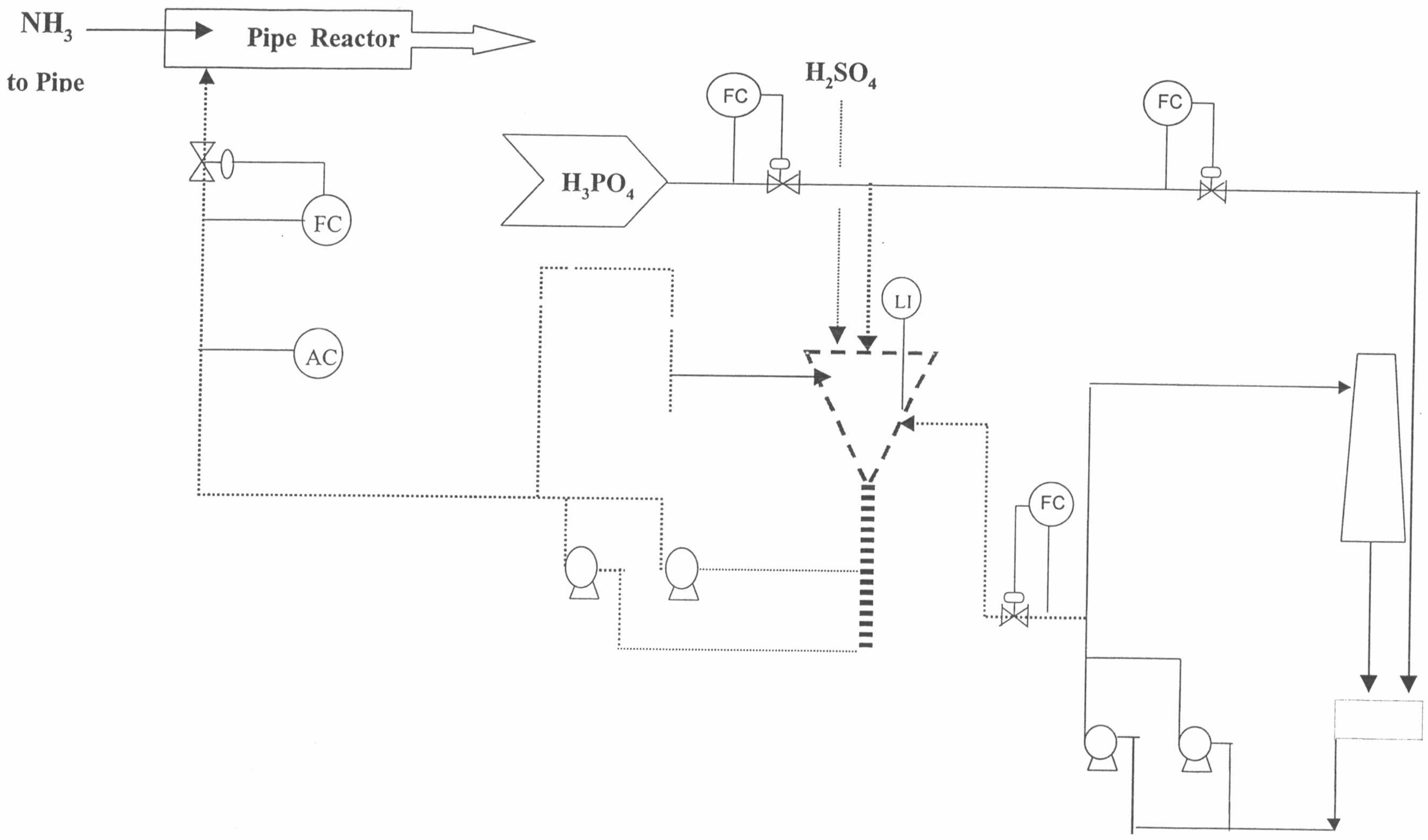


Figure (1.3) Ammonium phosphate-sulfate synthesis in reactor of NP/NPK rotary drum granulated fertilizer