Agricultural Marketing Policy Center

BRIEFING

Briefing No. 112 **September 2014**

The Production of Urea: A Common Nitrogen Fertilizer

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Objective Analysis For Informed Decision Making

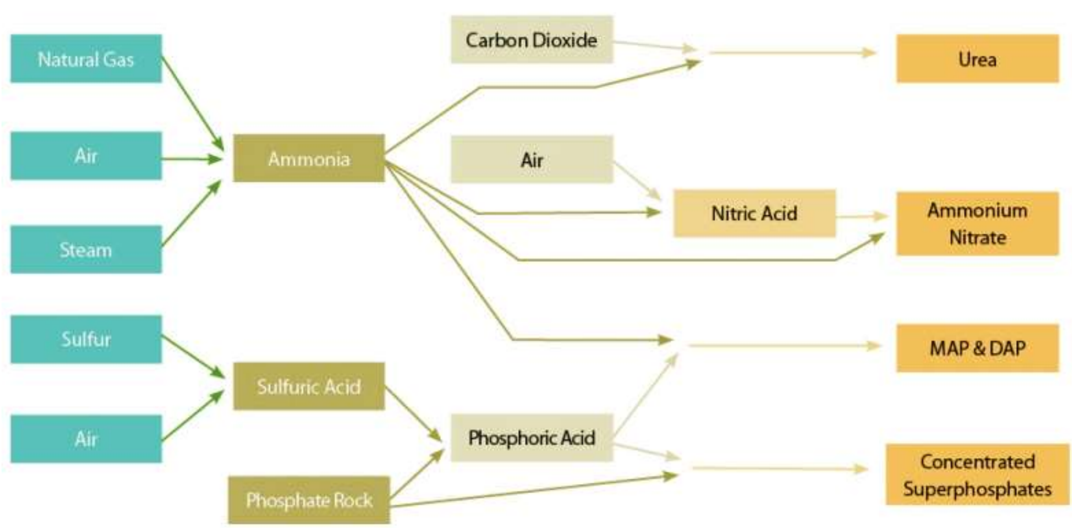
Introduction

Most agricultural fertilizers contain three essential plant nutrients — nitrogen, phosphorus, and potassium — as well as small amounts of certain "micronutrients," such as zinc, sulfur and other metals necessary for plant growth. Nitrogen is required for the formation of plant proteins and is the most widely applied nutrient. Although nitrogen is naturally present in soil and air, it generally cannot be used by most plants in its raw form. Fertilizer manufacturers, therefore, convert atmospheric nitrogen into usable forms to enhance crop production. Commercial conversion processes involve ammonia production (Briefing Paper 108). This briefing paper focuses on the processes used to produce urea which, after nitrogen solutions, is the second most common fertilizer end-product used in the United States.

Urea Production Process

Urea is an organic chemical compound that can be synthetically produced in transparent liquid, crystal, or solid forms. For economic efficiency reasons, urea is manufactured in integrated production processes in which ammonia is incorporated into various fertilizer products. Figure 1 shows the fertilizer end-products derived from combinations of ammonia and phosphate, including urea.

Figure 1: Process Flow Diagram for Fertilizer Production

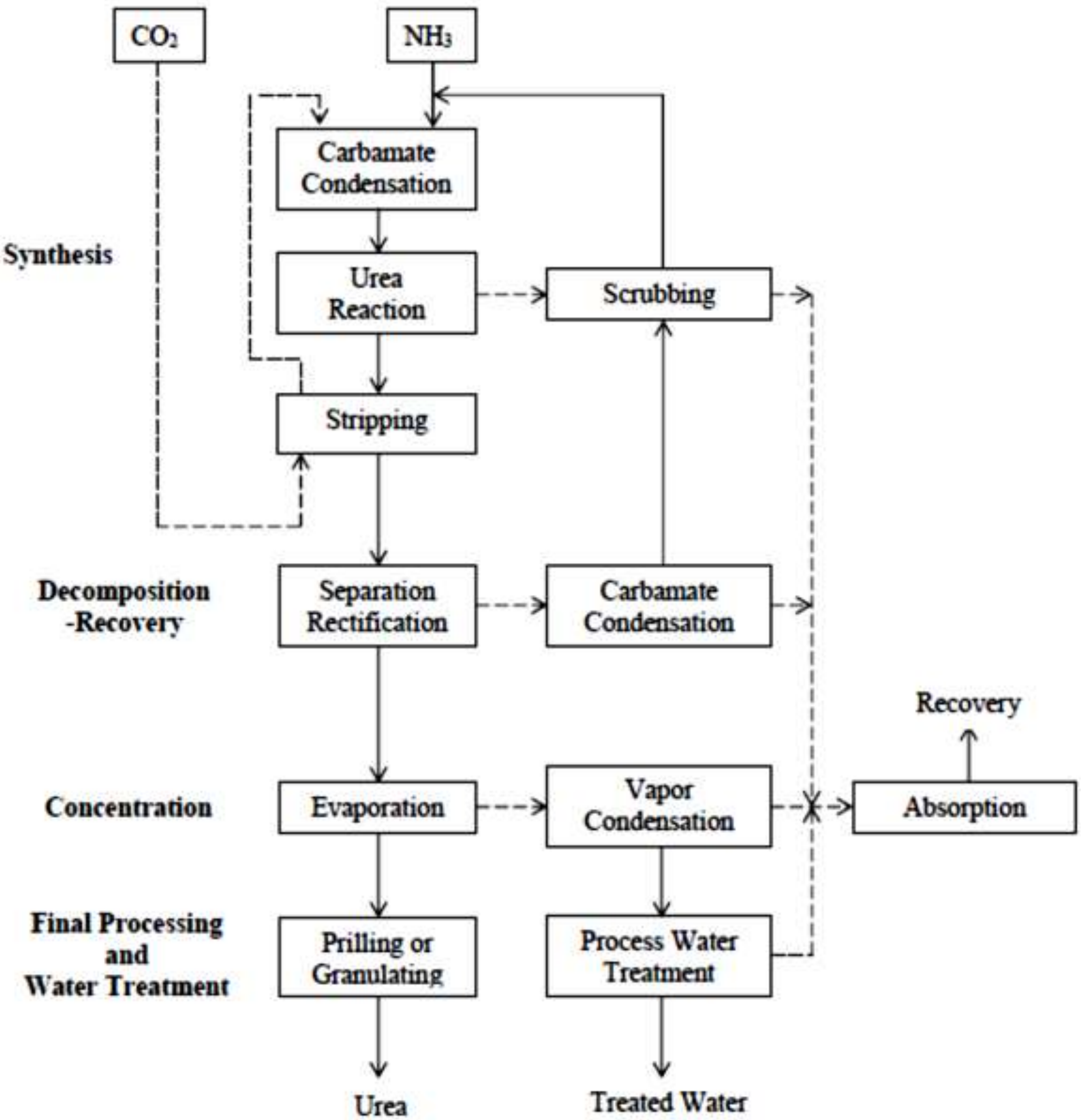


Source: Fertilizer 101

Urea is produced by reacting liquid ammonia with carbon dioxide using the Bosch-Meiser process. Because large quantities of carbon dioxide and excess steam are obtained as by-products of ammonia production, urea production plants reduce per unit costs by integrating with ammonia manufacturing processes. Urea manufacturers also reduce their production costs by recovering and recycling heat, steam, and impurities generated in the urea production process.

Urea is produced jointly with ammonia and manufactured in a four-step process that includes synthesis, decomposition, recovery, and purification (or concentration) (Figure 2). The process varies among processing plants with respect to how urea is separated from reactants and how ammonia and carbon dioxide are recycled. The production process can also be adjusted to obtain different types of end-products, such as concentrated solutions for granulated urea.

Figure 2: Urea Production Processes



Source: www.cheresources.com/ureamodeling.pdf

In step one, carbon dioxide is compressed at high temperatures (approximately 374 degrees Fahrenheit) using steam pressure. Compressed carbon dioxide and liquid ammonia is pumped into a synthesis/urea reactor (a large pressure vessel) that is then heated to a temperature of 356 degrees Fahrenheit and pressurized to 2,031 psi to produce ammonium carbonate.

In step two, ammonium carbonate is slowly converted to urea, water, and excess ammonia through a decomposition process. Some of the mixture cannot be converted into either urea or water. Therefore, in step three, remaining ammonium carbonate and excess ammonia is separated and recycled through a stripping process. The procedure is accomplished by routing carbon dioxide and ammonia gasses through a stripper, which separates the free ammonia from carbon dioxide and directly transfers the elements to a carbamate condenser for steam compression. The result is reconstituted ammonium carbamate, which is then returned to the urea reactor for reprocessing. The stripping process is important for a plant's efficiency because it increases urea production, improves productivity, and reduces per unit production costs.

In step four, purification of the urea solution which is now composed mostly of urea and water, is accomplished by heating the solution in a vacuum. This process removes some water through evaporation resulting in concentrated urea. Any urea crystals formed during the production process are heated and dissolved into the solution.

Maintenance Issues

Urea producers face challenges in maintaining their plants. Ammonium carbamate solutions have notoriously corrosive effects on pumps and tubes, even those made with the most corrosive-resistant forms of stainless steel. Traditionally, corrosion was minimized by continuously injecting small amounts of oxygen into the production process to establish a protective oxide layer on exposed stainless steel surfaces. Given that this technique can be volatile and risky, many companies have installed less-corrosive forms of stainless steel so that smaller amounts of oxygen are needed. Some plants replace stainless steel tubes with titanium or zirconium tubes to reduce corrosion.

Urea Products

Ninety percent of global urea production is used as fertilizer. The other ten percent is used in animal feeds and as diuretics. Urea products typically contain 46 percent nitrogen and are easier to store than ammonia since no refrigeration or pressurization is required. Nonetheless, urea products are generally structurally more fragile than ammonium nitrate and have a greater potential for N loss through ammonia volatilization (i.e., the natural conversion of dissolved ammonia to ammonia gas which is then lost to the atmosphere). Hence, handling, storage, and soil incorporation issues must be managed. Urea is typically sold in solid form either as prills (the most common form of urea) or granules, but can also be produced as a translucent solution that can be reacted with formaldehyde under acidic conditions to create slow release fertilizers (Figure 3). Granules tend to be larger and harder than prills, but both are chemically-equivalent small white pellets ranging from 1 to 4 millimeters in diameter.

Figure 3: Examples of Urea Granules and Prills

(a) Granular Urea (b) Prilled Urea

Prilled urea can be produced less expensively than granules using well-established production technologies and better resist deterioration when blended with other products. Granulated urea is less restricted in terms of size and shape, has a higher crushing and impact strength, and a lower propensity to deteriorate during bulk storage and handling.

Urea Prill Production

Urea prill production uses liquid forms of urea or ammonium nitrate. Liquid is transported to the top of a prilling tower (Figure 4) and dropped either through a system of spherical openings that are 1mm to 4mm in diameter or through a rotating perforated bucket. The droplets crystalize into hard prills, which are then collected, sorted by size, and sent to a bagging facility for packaging and shipping (Figure 5).

Figure 4: Duncan Fertilizer Prilling

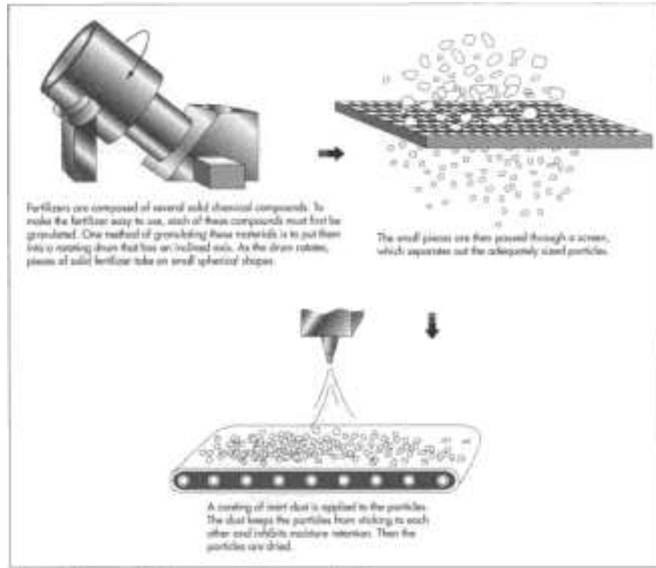
Source: http://enggyd.blogspot.com/2010/09/snamprogetti-urea-process-description.html

Urea Granular Production

In general, granulation processes are more capital intensive than prilling processes. Nonetheless, this production method has some important advantages, such as the ability to blend different compounds into granules throughout the process.

Two distinct granulation processes are used—one that uses solid urea and another that uses liquid urea. In the first process, solid urea is placed into a rotating drum with an inclined axis (Figure 5). As the drum rotates, pieces of solid fertilizer take on small spherical shapes. The small pieces are then passed through a screen that allows smaller sized granules to fall through the screen and captures larger sized granules on top (granules that need resizing are then crushed and returned to the drum). Next, a coating of inert dust is applied to the particles to keep each pellet separated and prevent moisture retention. Finally, the particles are dried and if urea granules are to be mixed with other fertilizers, the mixing is done in a vessel with rotating rods. The fertilizer is then loaded into a hopper and either packaged for bulk shipment or into bags.

Figure 5: Granulated Urea Production



Source: www.madehow.com/Volume-3/Fertilizer.html

Granules can also be produced by spraying liquid urea onto seed granules in a granulator. The granulator receives seed granules at one end and discharges coated granules at the other end. Granules are then dried, cooled and sorted using the screen process described above, except that oversized granules are crushed and combined with undersized granules for use as seeds in the granulator.

Summary

Urea is a common agricultural fertilizer and is produced by reacting liquid ammonia with carbon dioxide as part of an integrated operation in which ammonia is the main component manufactured at a production site. This process converts nitrogen into a form for effective delivery to crops. Substantial plant efficiencies and cost savings are derived from integrating urea production with ammonia production at the same plant through recycling steam, unprocessed ammonia, and ammonium carbonate.

Briefing paper 111 describes the production process used to obtain ammonia, which is required for urea production and the production of other nitrogen fertilizers, ammonium nitrate, and nitrogen solutions (UAN).

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