CHEMSYSTEMS

PERP PROGRAM

Report Abstract

Urea
PERP06/07S3

April 2009

Nexant

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INTRODUCTION

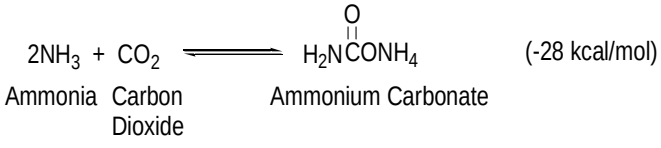
Urea is one of the most useful products made by the global chemical industry today. It is:

- The most important nitrogenous fertilizer in the world. It makes a major contribution to food supply, particularly in the third world. With 46 percent nitrogen, it is the most concentrated form of solid nitrogenous fertilizer, and therefore, has a logistic advantage over ammonium nitrate fertilizers. It is preferred for rice crops because of its slow nitrogen release characteristics.
- One of the raw materials in urea formaldehyde resins, the dominant wood glues in particle board, chip board, and plywood.
- A raw material for melamine and other chemical syntheses.
- An animal feed additive that is converted to protein by ruminants.

Produced in more than 290 plants around the world, total global demand in 2006 was well in excess of 100 million tons, and is forecast to grow to the year 2012. Urea is produced in many countries, but economics favor those with inexpensive natural gas, and it is a major product in world trade.

In 1828, Wohler discovered that urea could be produced from ammonia and cyanic acid, making urea the first organic compound synthesized from inorganic compounds. Today, urea is normally produced commercially from ammonia and carbon dioxide via ammonium carbamate, as shown below. Commercial ammonia plants produce CO_2 as a by-product, and so urea plants are built adjacent to ammonia plants because carbon dioxide is expensive to transport. Some energy integration can also be achieved.

In the first step, ammonia and carbon dioxide combine to give ammonium carbamate also known as ammonia carbonate. This reaction is fairly exothermic:



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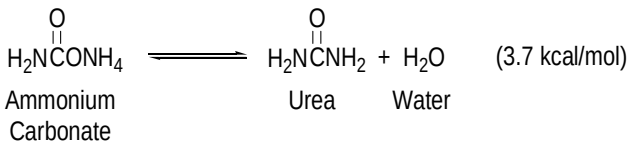
The second step is the relatively slow dehydration of ammonium carbamate to yield urea.



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The dehydration is a mildly endothermic reaction. Thus, overall formation of urea from ammonia and carbon dioxide is exothermic. Although the illustrated chemistry is viewed as two separate reactions, in actual practice the two steps occur virtually simultaneously.

There are many variations of the urea process, but all modern processes proceed by the same basic chemical route. The final form of the product may be as prills, granules, or now rarely, crystals.

The manufacture of urea has a number of inherent difficulties which are outlined in this ChemSystems report.

TECHNOLOGY

The main processes used today, in the production of urea, are the stripping processes offered by Stamicarbon, Snamprogetti, and Toyo Engineering Corporation. Urea Technologies Inc. offers a total recycle process. These licensors and Urea Casale also offer a number of process improvements for revamps to existing plants based on low energy consumption, improvement of environmental impact, and product quality. However, licensed urea processes are only available by Stamicarbon, Snamprogetti, Toyo Engineering Corp. (TEC), and Urea Technologies Inc.

The urea production process consists of the following five process steps: **Synthesis, Decomposition** (unconverted ammonium carbamate is decomposed back to ammonia and carbon dioxide)**, Recovery** (gases released from the decomposition step are scrubbed out with water, cooled, and usually totally or partly recycled to the synthesis section)**, Concentration (**excess water is removed to produce molten urea) **and Finishing (**concentrated urea solution from the concentrators is processed either through a prilling tower or urea granulator, or is crystallized and re-melted to produce industrial grade urea).

The process known as stripping is a total recycle process designed to decompose residual ammonium carbamate in reactor effluent without reducing the pressure. Stripping processes quickly became the favored route for urea production. In general, the stripping process requires a tall structure to house the reactor, stripper, and condenser. Process flow diagrams and process descriptions of the following are given in the report:

- Snamprogetti's Ammonia Stripping Process
- Stamicarbon Urea 2000plus™ CO_2 Stripping Process
- Stamicarbon Urea 2000plus™ Mega Plant Concept
- TEC Advanced Process for Cost and Energy Saving (ACES)
- TEC ACES 21®

In the partial recycle process, unconverted NH_3 from the stripped urea solution and from the reactor offgas is neutralized with nitric acid to form ammonium nitrate. This solution is then mixed with urea solution from the synthesis section to yield a solution of urea ammonium nitrate (UAN). Process flow diagram and process description of the following is given in the report:

- Stamicarbon Partial Recycle UAN Process

In the once through process, the unconverted NH_3 gas from the urea reaction is used to produce ammonium salts by absorbing the NH_3 in sulfuric, nitric, or phosphoric acid. The CO_2 passes through the acidic environment. Process flow diagrams and process description of the following is given in the report:

- Stamicarbon Once-Through Process

Urea is readily soluble in water and may be crystallized from solution. However, crystallized urea is usually unsuitable as a commercial product because of its storage and handling properties.

In the development of solid urea as a fertilizer, including the ability to be stored and transported in bulk, it became essential to have a solid product of sufficient strength and in a form that would not cake.

- The prilling process was developed to fulfill this role and is discussed further in the report

Granulation offers more flexibility in choosing particle size, and produces particles with more strength and abrasion resistance than prills – this is discussed further in the report exemplified by:

- Stamicarbon Fluidized Bed Granulation Technology
- Uhde Fertilizer Technology (UFT) Fluidized Bed Granulation Technology
- TEC Spout-Fluid Bed Granulation Technology
- Snamprogetti Drum Granulation Technology
- Snamprogetti Fattening Technology

Crystallization is a low temperature process and a urea product with low biuret content may be obtained by this route. This process is briefly outlined.

REVAMP OF UREA PLANTS

The decision to revamp a plant and the extent of such revamping is dependent on many factors, eventually determined by cost savings and capital investment payout. It should be emphasized, that in the case of urea plants, natural gas prices (the key feedstock in the production of ammonia) can also play a mayor role in the revamping of urea plants. In cases of inexpensive raw materials, efficiency features are usually economical only in conjunction with capacity increases. Many revamping possibilities available offer, among other things, increased capacity as well as improved energy efficiency.

The number and extent of these improvements depend on the design generation of the plant and economic considerations including return on capital investment. Also, overall plant operation can be improved which can result in maximized urea production.

- Stamicarbon has developed a series of revamping concepts which are outlined in the report, for example, the In-line Medium – Pressure Recirculation Concept and the Medium-Pressure Recirculation Add-On Concept, the Pool Condenser Concept, the Combi-Reactor Concept

- Toyo Engineering Corporation (TEC) offers different technology options on revamping and/or renovation of conventional solution recycle urea process in order to improve the efficiency of the plant as well as the quality of the urea product. TEC's ACES 21 revamping technology is discussed further in the report.

TECHNOLOGY DEVELOPMENTS

The technology for producing urea has been used for over 35 years and must today be considered quite mature. However, every one of the many steps used in urea production has been the subject of numerous improvements over the years and important developments are constantly being made with respect to process, equipment design, and product finishing.

The companies most active in this area are Urea Casale, Toyo Engineering Corporation (TEC), Yara International and DSM.

A brief overview of the type of research being performed to improve the urea production process is given. The following are outlined in the report:

- A method for improving the crushing strength of the urea product while exhibiting a low caking tendency and reduced dust formation.
- A urea synthesis process in which a reaction mixture (consisting of urea, unreacted ammonia, unreacted carbon dioxide and water) was stripped from unreacted ammonia and unreacted carbon dioxide using carbon dioxide feedstock. Additionally an apparatus for the above urea synthesis process that included a vertical condensation and synthesis column and a stripper.
- The use of natural gas to produce ammonia and carbon dioxide which in turn are used in the production of urea in the same processing line, industrial area, or in the same urea production plant.

ECONOMIC ANALYSIS

Costs of production estimates for the following have been carried out:

- Ammonia production by reforming of natural gas, located on the U.S. Gulf Coast
- Urea production from ammonia stripping in the United States
- Ammonia production by natural gas reforming in the Middle East
- Urea production from ammonia stripping in the Middle East

The major contributor to urea cost is the cost of ammonia. Since all the urea plants are situated next to ammonia facilities, the effect of transferring ammonia into the urea process at cash cost and full cost has been examined. Additionally, a cost of production estimate for the production of urea based on market price ammonia is shown.

- Prilled and granulated urea cost of production estimates, on the Middle East, are presented.

COMMERCIAL ANALYSIS

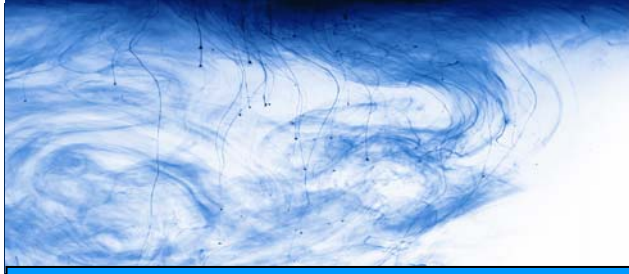
Urea is used as a solid nitrogen release fertilizer, because it has a high nitrogen content (46 percent), compared with 34 percent for ammonium nitrate and less for ammonium sulfate.

The high nitrogen content of urea reduces transportation costs per ton of nutrient. This, together with its lower solubility and absence of safety considerations make it more suitable for deep-sea expert and use in the tropical climates of Asia and Latin America. As these are growing economies with high populations, urea is the most widely used nitrogen fertilizer.

In addition to fertilizer uses, chemical uses such as melamine, resins, pharmaceutical and others are outlined.

This section also provides a regional market review for urea for the North America, Western Europe, and Asia Pacific. The forecast timeframe is out to 2011.

- Supply, demand, trade data are provided for the United States, Western Europe and Asia Pacific (Japan)



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