Large Scale Urea Granulation Plants based on TEC Technology

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INTRODUCTION

Toyo Engineering Corporation (TEC), a worldwide engineering contractor and one of major urea process licensers, has its own technologies for both urea synthesis and granulation. As of the end of 2000, 92 urea plants and 9 urea granulation plants are based on TEC technologies. The TEC own granulation technology so called Spout-Fluid Bed Granulation was developed in the early 1980s. In the year 2000, a 2,000 MTPD urea granulation plant which is the latest and the largest experience for TEC started operation successfully, demonstrating its excellent and reliable performance with aqueous urea solution feed. Encouraged at the experience of the 2,000 MTPD unit, TEC has completed the study on design of larger scale granulation unit of 3,500 MTPD capacity to meet the recent requirement for urea plant combined with 2,000 MTPD ammonia plant. The following state-of-the-art technology and know-how have fully supported the study:

- Rigorous model developed and up-dated incorporating the data obtained in pilot plant and actually operating industrial scale plants to simulate the granulation mechanism and whole granulation process using computer.
- Actual and various vendor proposed performance data of major equipment comprising the process, i.e. crushers and screens.

Table I
Project experience

OWNER	LOCATION	CAPACITY (MT/D)	ON STREAM
1) Mitsui Toatsu Chemicals, Inc.	Chiba, Japan	50	1975
2) Petrochem Ltd.	Kapuni, New Zealand	470	1983
3) Mitsui Toatsu Chemicals, Inc.	Osaka, Japan	100	1983
4) SKW Piesteritz GmbH	Piesteritz, Germany	1,200	1995
5) Petrochem Ltd.	Kapuni, New Zealand	750	1997
6) SKW Piesteritz GmbH	Piesteritz, Germany	500	1998
7) Ningxia Chemical Works of CNPC	Ningxia China	1,740	1999
8) P.T. Pupuk Iskandar Muda (PIM-2)	Aceh, Indonesia	1,725	(2002)
9) Lutianhua Group Inc. (CNTIC)	Sichuan, China	2,000	2000

This paper outlines the essence of TEC urea granulation technology, i.e. the Spout-Fluid Bed Granulator, the uniquely designed dust scrubber, the rigorous granulation process flow simulator, the performance of the 2,000 MTPD unit and the design philosophy of 3,500 MTPD unit.

PROCESS DESCRIPTION

Figure 1 shows a typical flow diagram of TEC Urea Granulation Process. The Urea Granulation process consists of following three sections.

- granulation section
- recycle and product cooling section
- dust removal and recovery section

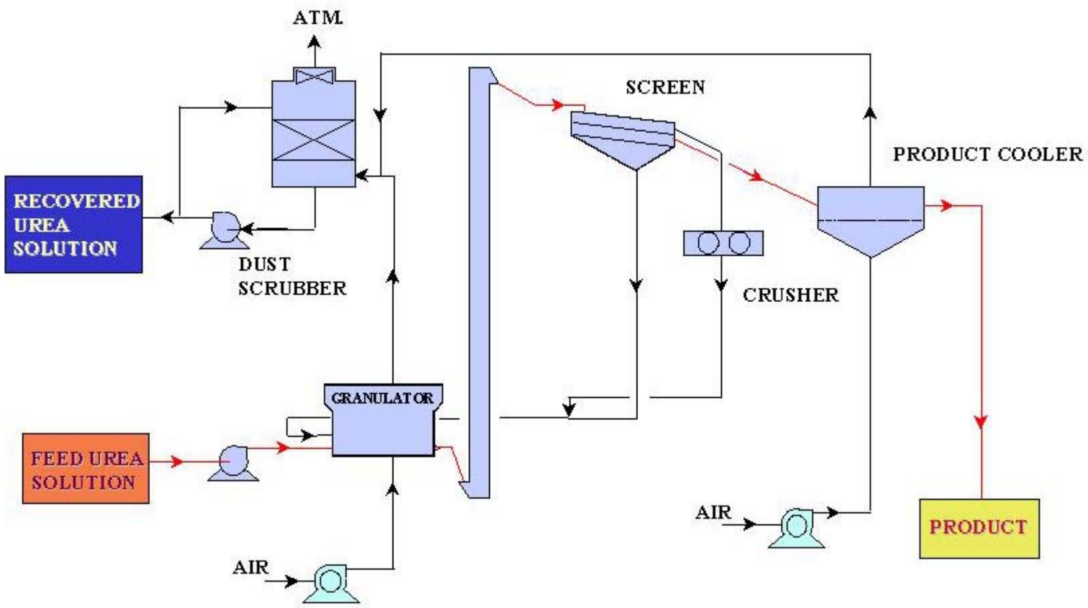

Fig.1: TEC urea granulation process flow diagram

Aqueous urea solution from urea plant is fed to the granulator to enlarge recycle particles in the granulator. In the granulator, the granules are dried and cooled simultaneously. The granulator is operated at 110-115ºC and at slightly negative pressure. Enlarged urea particles are cooled to about 90ºC in the after-cooler inside the granulator to be transported to the recycle section.

The discharged granules are separated into three sizes, product, small and large size by the screen. Product size granules are further cooled below 60ºC in the product cooler to be sent to the urea storage or bagging facility. Large size granules are crushed by the crusher. The crushed particles and smaller size particles from the screen are recycled to the granulator as seed.

Urea dust contained in the exhaust air from the granulator and the product cooler is scrubbed in the dust scrubber by contacting counter currently with aqueous urea solution. The urea dust content in the exit air of the dust scrubber is 30 mg/Nm3 or less. Urea recovered in the dust scrubber, approximately 3-4 % of production rate, is recycled to the urea plant as 45 wt% urea solution.

Any other urea granulation processes available in the world have similar flow schemes, however characteristics and performance of the process strongly depend upon the granulator design. The features of TEC Urea Granulation Process are given below:

- High Energy Efficiency:
  1) No requirement of compressed atomizing air for granulator reduces power consumption;
  2) Seed circulation at moderately high temperature (= 90ºC) minimizes cooling air requirement and heat removal in the process;
  3) Optimal bed depth minimizes pressure loss in the granulator;
  4) Uniquely designed low pressure drop dust scrubber minimizes power consumption of induced fan(s)

Table-II shows a typical steam and power consumption of TEC Urea Granulation Process.

Table II

Typical specific utilities consumption

Steam	0 – 0.03MT/MT
Power	23 – 25kWh/MT

Note: ambient temperature = 30 - 35ºC

In the case that water cooled bulk flow cooler is applied for product cooling instead of fluidized bed cooler, the power consumption is further reduced by about 4 kWh/MT. Since its first application in 1993, TEC has been ready to apply the both options in granulation plant design, i.e. the bulk flow cooler and the fluidized bed cooler considering site conditions, energy cost and client's requirement.

- High Product Quality
  1) Rapid cooling of granules in the granulator with minimum residence time reduces biuret formation to negligibly small;
  2) Efficient drying in the granulator reduces granule moisture low enough to increase product hardness;
  3) Optimal combination of spouted bed and fluidized bed produces round and uniform granules.

Table-III shows typical quality of the granules produced by TEC Urea Granulation

Process.

Table III
Typical product quality

Total Nitrogen	46.3wt%
Biuret	0.7wt%
Moisture	0.25wt%
Formaldehyde	0.45wt%
Size (2-4mm)	95wt%
Hardness	3.5kg at 3mm

- Low Urea Dust Emission
  1) Optimal spouted bed air velocity minimizes dust formation in the granulator.
  2) Uniquely designed low delta-P dust scrubber proven through application to twelve prilling towers and seven urea granulators reduces urea dust to less than 30 mg/Nm3.

TEC SPOUT-FLUID BED GRANULATOR

Figure 2 shows a schematic diagram of TEC Spout-Fluid Bed Granulator. The granulator consists of spouted beds and fluidized bed on the perforated plate, spray nozzles and air duct manifolds. Each spouted bed has one spray nozzle. Recycle urea granules are enlarged while passing through the spouted beds and the fluidized bed. Aqueous urea solution (> 95wt%) is sprayed into the spouted beds through pressure spray nozzles.

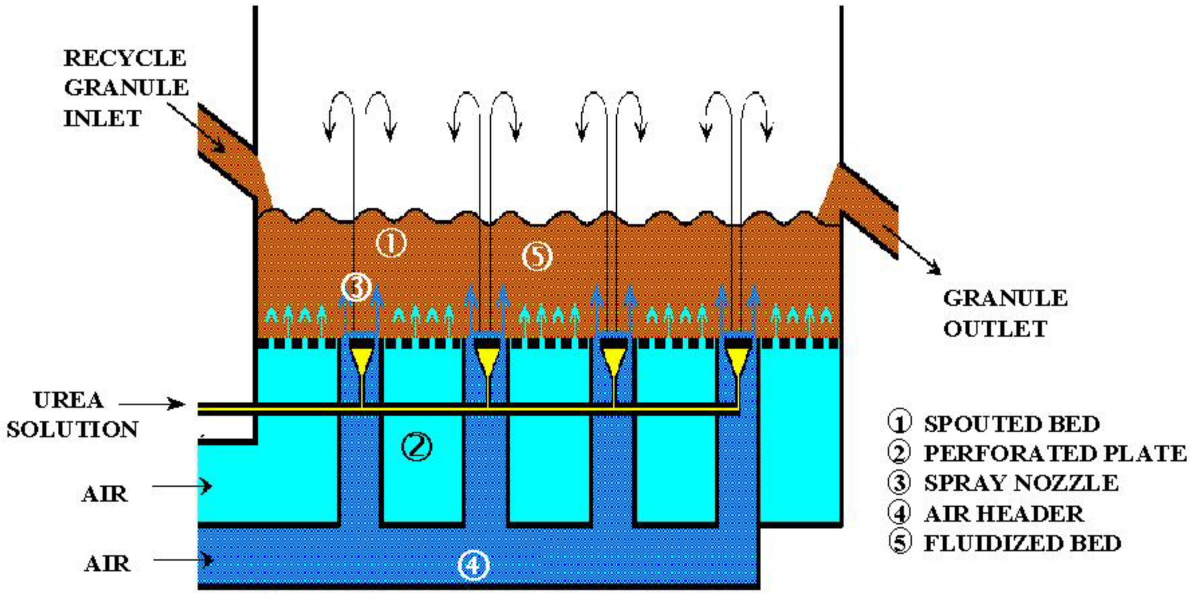

Fig. 2: TEC spout-fluid bed granulator

Vigorous mixing in the spouted bed gives round and uniform granules. Since air introduced for spouting and fluidizing not only removes urea solidification heat but also evaporates water contained in the sprayed aqueous urea droplets and granules, the urea granules are dried to less than 0.25wt% moisture content at the exit of the granulator. Owing to the drying effect in the granulator, cost and energy consumption in the urea process plant can be reduced.

Industrial scale granulator has multi-stage spouted bed arrangement, therefore the granulator is simply scaled-up by increasing the number of the spouted beds.

TEC UNIQUE DUST SCRUBBER

A major source of the gaseous pollution from urea granulation plant is urea dust. For industrial application of the dust scrubber, the following technical and economical considerations are made.

- Urea dust contains extremely fine particles
- Low pressure loss through the dust scrubber minimizes the running cost
- Installation cost can be reduced and the design can be simple and flexible, being independent of dust scrubber manufacturers' know-how

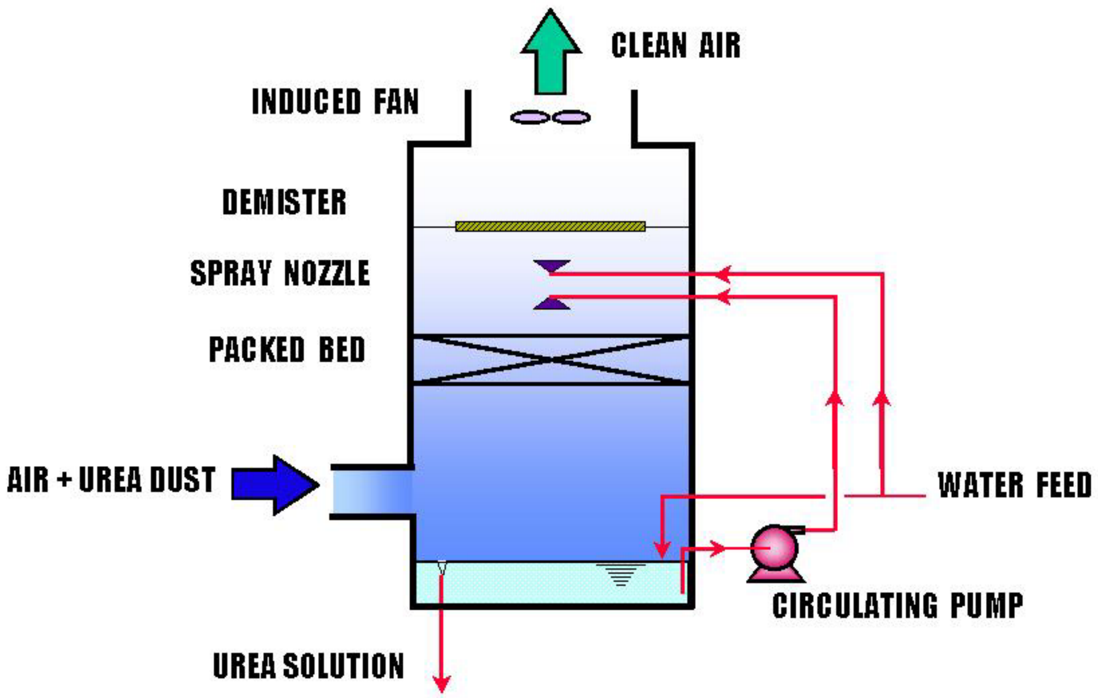

Fig. 3: TEC Dust Scrubber

Supported by 19 plants applications and intensive R&D effort including pilot plant testing, TEC has further improved the dust scrubber design aimed at better dust collection efficiency and less installation cost. By applying packed bed type dust scrubber, the high dust collection efficiency with low pressure drop and low installation cost is realized.

In general, dust collection efficiency (*E*) in the dust scrubber is expressed by the following function:

$$E = f(k, \eta, h, L)$$

where *k* = Packing coefficient, η = dust collection efficiency of sprayed water, *h* = packing effective height and *L* = liquid load.

The equation expressing correlation between *E* and other design variable and parameters has been developed and enables TEC to design the dust scrubber very flexibly so as to meet the various project conditions.

Figure 3 shows a schematic diagram of the dust scrubber. The urea dust in the air coming from the granulator and local dust collection points are scrubbed in the dust scrubber by contacting counter currently with sprayed aqueous urea solution in the packed bed. Then the air is exhausted into the atmosphere by the induced fan after mist elimination by a de-misting pad. The urea dust content in the exhaust air is 30mg/Nm3 or less and the pressure loss through the packed bed is only 45 mmH2O.

UREA GRANULATION PROCESS SIMULATOR

Since the R&D period of the urea granulation process in early 1980s, TEC has developed a urea granulation process simulator by combining a theoretical approach of the granulation process and data obtained in the pilot plants. The granulation process simulator has been continually improved and up-dated incorporating commercial scale plants' data. The simulator rigorously simulates the whole urea granulation process of a steady state for the use of both process design and analysis. TEC has successfully scaled-up the granulation process design from 50 MTPD in 1977-80 to 2,000 MTPD in 1999-2000 by fully utilizing the simulator.

Figure 4 shows a typical process flow scheme for the urea granulation process simulator. The simulator simulates not only the granulator but also the cooler, the screen, the crusher and the dust scrubber. Flow scheme for process simulation can be flexibly arranged. The simulator predicts following process variables for each stream:

- mass and heat flow
- composition
- number of nuclei
- size distribution

The simulator is powerful enough to study the following items as well:

- predict performance of turn down operation
- determine operation conditions of the granulator and the coolers

- determine spouted bed arrangement in the granulator
- select screen type, mesh opening, and number of stages, of which separation efficiency is based on screen manufacturers' shop test and/or actually operating plant data
- estimate the feed rate to the crusher

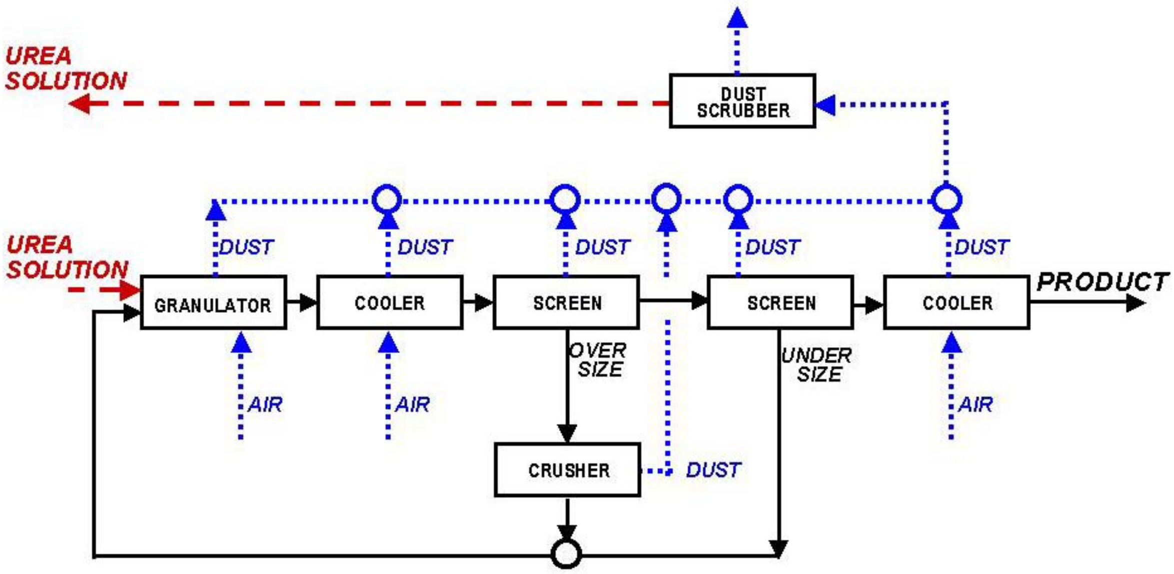

Fig. 4: Process flow scheme for simulator

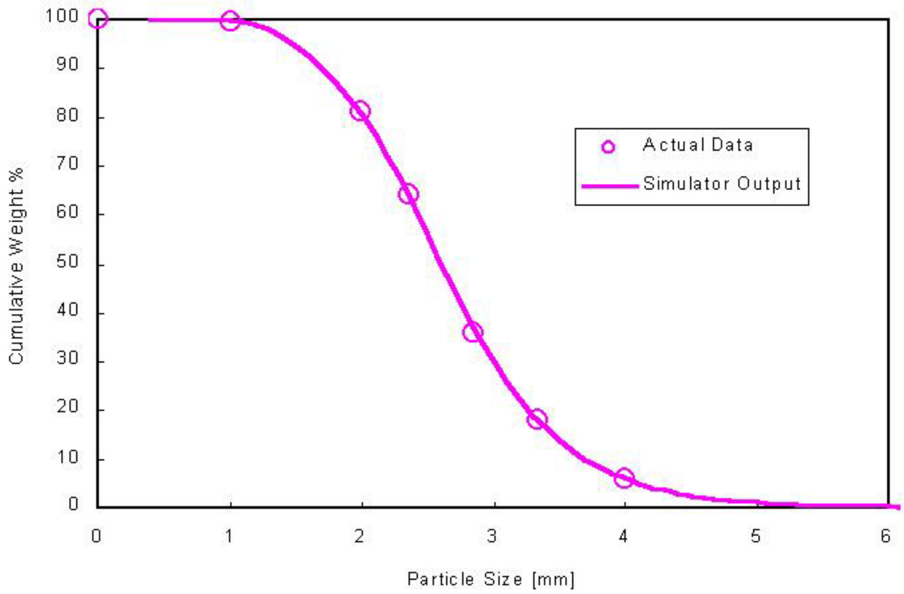

Fig. 5: Typical computer simulation result of granulator outlet

To simulate the granulation process precisely, theoretical equations for granulation by Kunii and Levenspiel and an experimental equation for particle growth rate developed based on pilot plant test have been incorporated for granulator modeling.

The particle growth rate is expressed as the function shown below:

$$R = f\,(F, w, d_p\,, P_0)$$

where R = particle growth rate, F = feed rate of urea solution, w = weight of solids in spouted bed, d_p = particle diameter and P_0 = size distribution function of recycle particles.

The rigorous granulator model simulates the granulator exit particle size distribution very accurately, as shown in Figure 5, backing up reliable scale-up of the granulator.

To estimate the water evaporation in the granulator, the following functional equation is incorporated into the granulator simulation.

$$M = f\,(C_t\,, S, H)$$

where M = moisture of granule, C_t = coated thickness of granule, S = total surface area of granule and H = relative humidity.

Granulators designed based on the above simulation model have successfully demonstrated their performance for aqueous urea solution feed.

EQUIPMENT LAYOUT

Figure 6 shows a bird's-eye view of a typical 1,700 MTPD TEC Urea Granulation Process plant. As can be seen, the building for granulator and other solid handling equipment is very compact.

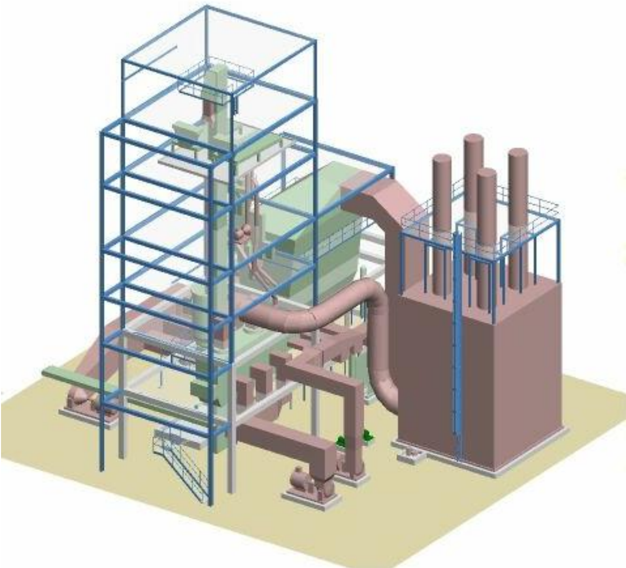

Fig. 6: 3-D graphic representation of TEC granulation plant

TEC Urea Granulation Process has alternative layout options, i.e. the dust scrubber can be installed on the top to reduce the plot area. This option can be attractive for the case that available area is very limited, for example, the case for prill tower conversion to granulation. Four granulation plants have employed this layout.

LARGE SCALE GRANULATION PLANTS IN CHINA

Two large scale urea granulation plants based on TEC technology, of which respective nameplate capacity is 1,740 MTPD and 2,000 MTPD, have been commissioned in China in 1999 and 2000. Both plants have single train TEC Spout-Fluid Bed Granulator designed to receive aqueous urea solution as feed. The both plants are designed to be capable to produce either 2-4 mm product or 5-8 mm product, depending upon the market demand. In the 2,000 MTPD unit project for Lutianhua Group Inc., (LTH) which aimed at the total conversion of existing prilling tower to granulation, the following advantages have been demonstrated:

- 2,000MTPD production with aqueous urea solution feed
- Remarkably low urea dust emission (= 5 mg/Nm3) by uniquely designed dust scrubber
- Low production cost owing to low utilities consumption
- Easy and smooth start-up in large capacity unit

Fig. 7 LTH 2,000MTPD granulation plant

This project came into effect in May 1999. TEC supplied the process design package and proprietary equipment as process licenser. China Wuhuan Chemical Engineering Corporation (CWCEC) carried out detail engineering and LTH performed procurement and construction. Owing to the efficient project coordination and cooperation among TEC, CWCEC and LTH, the plant started operation in July 2000, within only 14 month after the effective date of contract. Some details of the project are introduced below.

Process flow scheme

The process flow scheme of the LTH Urea Granulation plant is essentially same as that of Figure 1 except for the dust scrubbing system. Because of the ammonia emission regulation, TEC has adopted two stage packed bed dust scrubber. Lower bed is for urea dust removal by water scrubbing and upper is for gaseous ammonia removal by nitric acid scrubbing.

Operation history

The plant went into operation in the beginning of July 2000 and the plant load reached 100% very smoothly. Performance test run was completed in October 2000. Table IV shows the operation history of the LTH Urea Granulation plant. The plant has operated successfully producing good quality product for both export and domestic use.

Table IV
Operation history of Lutianhua granulation project

		Maximum Daily Plant Load	Remarks
On Stream	Jul '00	103 %	★ Plant Load has reached 100% very smoothly.
	Aug '00		★ Bucket Elevator Belt Repair Work
	Sep '00	100 %	
from middle of Sep '00 to middle of Oct '00			★ Production of Prill due to marketing reasons
Performance Test	Oct '00	107 %	

STUDY ON LARGER SCALE UREA GRANULATION PLANT

Considering recent demand for larger-scale urea plant, TEC has reviewed the design of a 3,500 MTPD urea granulation unit utilizing the state-of-the-art granulation process simulator, full knowledge and know-how on solid handling equipment and machinery, and incorporating the latest experience of the 2,000 MTPD unit.

Process flow scheme and equipment trains

Process flow scheme for a 3,500 MTPD unit is basically same as shown in Fig.-1. The granulator, dust scrubber and product cooler can be designed in single train. For the solid handling equipment and machinery, such as the bucket elevator, the screen and the crusher, the number of trains should be carefully determined respectively, considering capacity limitation of each item and equipment layout.

Granulator

Basic philosophy for granulator scale-up is to increase the number of spouted bed proportionally to the production capacity. However, the following precautions should be considered for a single train granulator design for 3,500 MTPD capacity.

- The uniform distribution of recycle particles to the inlet of the granulator is essential. If the granulator width is considerably wider compared to the length, in-uniformity of inlet seed flow may be easily maintained to the exit of granulator, causing lower granulation and drying efficiency. In this point of view, granulator size should be increased lengthwise rather than widthwise.
- The granulator should be carefully designed so as to make uniform air distribution to spouted beds and fluidized bed. Air flow analysis with special computer software is applied to verify the design.
- In case that the granulator (lower section) is fabricated completely in the manufacturer's shop to be transported to the construction site, the granulator width should be 4 m maximum, considering limitation of in-land transportation. Site fabrication or assembling of partially pre-fabricated granulator should be also considered.

Recycle section

Four trains of screens and crushers will be appropriate to maintain satisfactory performance in product quality and reliability, considering the maximum capacity of present available machines. Other transportation equipment such as bucket elevators and belt conveyors will not be the bottleneck even for the 3,500 MTPD unit in terms of their availability, therefore, the number of trains of transportation equipment should be determined considering equipment layout, operability and maintainability.

CONCLUSION

Successful commissioning of a 2,000 MTPD unit has demonstrated the performance and reliability of the TEC Urea Granulation Process with aqueous urea solution feed and their scale-up philosophy. Further scale-up study has proved that 3,500 MTPD unit is feasible in combination of a single train granulator and other solid handling equipment in multiple trains. TEC, the only urea process licenser and engineering contractor that owns commercially proven urea synthesis, prilling and granulation process technologies, is ready to design a 3,500 MTPD granulation unit combined with a urea synthesis plant of corresponding capacity.

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