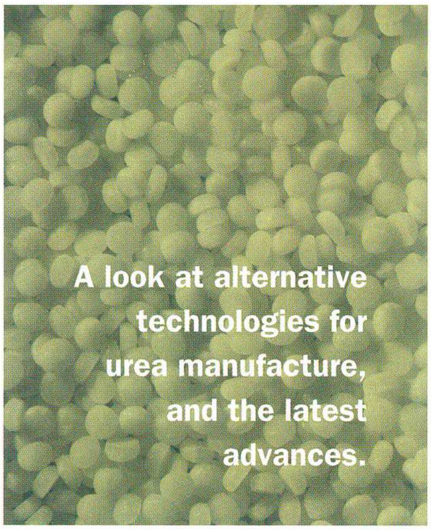


Prills, granular or pastilles?

Prilled and granular urea are made using totally different finishing processes. The fertility value is the same, but the prilled urea manufacturing process creates a smaller particle that is softer, making it more susceptible to damage during handling and storage. Prills are also more prone to caking, making them hard to handle. However, a new granular urea plant involves a higher capital expenditure than its prilled counterpart, and the economics of granular urea production have depended on the product being able to secure a price premium in the marketplace. With the steady addition of considerable new granular urea capacity, this price premium is being eroded. Meanwhile, a third technical route is now available for urea production and has gained popularity, namely pastillisation: we examine the merits of each process.

Prilled urea is produced when solid material is made by the direct solidification of molten urea droplets, the size of which almost equals the required final product size. This contrasts with granulation technology, which involves the solidification of successive layers or agglomeration of solution or melt on to the surface of seeds, which are separately fed into the granulator and are made to grow during their passage through the granulator by continual spraying. (*Prilling or Granulation of Urea*, F. Kars, Stamicarbon. Paper presented at IFA Technical Conference [November 1984].)

In a typical urea prilling process, a urea melt of 99.7% concentration is distributed in the top of a typical cylindrical tower by a rotating bucket. The urea droplets solidify and cool during their free fall in direct contact with ambient air flowing upwards. The prills are collected, screened and transported in the base of the tower by a rake conveyor and then transported to storage. It is also possible to delete the rake by installing a conical bottom in the tower, while the height of the tower can be reduced, depending on the design, by installing an additional product cooler.

Stamicarbon has been a leading supplier of urea prills technology. The company patented a process by which small seed particles are brought into the prilling tower to prevent under-cooling of the droplets, thus increasing the mechanical strength of the prills. Mechanical strength can also be increased by adding some formaldehyde or similar material. This in addition improves the storage characteristics of the product with respect to caking. Dust emissions from a prilling tower without an additional dust scrubber are typically higher, compared with granulation plants.

The design and operation of the prilling bucket exerts a major influence on product size and the product size distribution. Collision of the molten droplets with the tower wall as well as inter-droplet content causing agglomeration must be avoided. Normally prill diameters range from 1.6-2.0 mm for prilling operations.

Prilling technology has several limitations:

- The size of the urea prill is limited to under 2.0 mm in diameter. Hence the prill does not blend as well with other types of fertilizers of larger particle size. This can result in segregation in the mixture during handling processes and an unbalanced distribution of the fertilizer on crops.
- The prilling process can create significant dust, which can be in excess of 1.0% of manufacture, causes windage losses on application, segregates badly on handling and encourages rapid moisture and caking during storage.
- Prills tend to be weak in structure, having a crushing strength of less than 1.5 kg, and are prone to breaking down during handling and storage. This adds further to dust problems.

Granulation technology

These factors prompted the development of granulation technology, which results in the production of urea of larger particle size and hardness. With granulation, and depending on the process, a 95-99% urea feedstock is used. The lower feedstock concentration allows the second step of the evaporation process to be omitted or simplified. The basic principle of the process involves the spraying of the melt on to the recycled seed particles circulating in the granulator. A slow increase in granule size and drying the product takes place simultaneously. Air passing through the granulator solidifies the melt deposited on the seed material. (*Best Available Techniques: Production of Urea and UAN*, EFMA [2000].)

Processes using low-concentration feedstock require less cooling air, since the evaporation of the additional water dissipates part of the heat, which is released when the urea crystallises from liquid to solid. Processes using low-concentration feedstock require less cooling air, since the evaporation of the additional water dissipates part of the heat, which is released when the urea crystallises from liquid to solid. Processing using high-concentration feedstock requires less formaldehyde to be added to the urea melt, to attain the required product quality.

Most of the commercial processes available are characterised by product recycle, and the ratio of recycled to final product varies between 0.3 and 2.5. Contrary to prilling, where solid material is made by direct solidification of molten urea droplets, all granulation processes function by solidifying successive layers of conglomeration of solution or melt on to the surface of particles.

Because in most of the available technologies, growth is not uniform, so the granulate stream from the granulator is split into three fractions by screening:

- Oversize material (which is normally crushed to seed material and recycled to the granulator)
- Final product
- Undersize material (which re-enters the granulator as recycle and contributes to cooling)
- Vortex granulation.

Table 1: A comparison of urea production technology – prills vs. granulation

Stage	Prilling	Granulation
Evaporation	Yes	Yes
Melt dispersion	Yes	Yes
Cooling	Yes	Yes
Purification	Yes	Yes
Sorting	No	Yes
Grinding	No	Yes
Recycle return	No	Yes
Final cooling	No	Yes

Source: Nitrogen+Syngas/NIIK

Usually, the product leaving the granulator is cooled and screened before transfer to storage. Conditioning of the urea melt with formaldehyde prior to spraying is a requirement in the granulation process to enhance the storage and handling characteristics of the granular product and to limit dust formation in the granulator.

Several forms of urea granulation technology are available, including:

- Fluidised bed granulation
- Spouted bed granulation
- Falling curtain granulation or drum granulation.

The heart of the drum granulation process is a horizontally-aligned cylindrical drum, which rotates about its axis in a conventional manner. The interior of the drum is fitted with special anti-clogging lifters. (*Granulation and fattening of fertilizers using the Kaltenbach-Thüring Fluid Drum Technology*, E. Vogel. Paper presented at IFA Technical Conference [1992].)

The drum granulator is supplied with seed material, which is subjected to the dual operations of size enlargement and cooling or drying. This occurs progressively in the following cyclic sequence:

- Lifters raise the seed material to the upper part of the drum, where it falls on to the surface of the fluidised bed, where the product is cooled or dried.
- From the bed, product falls to the lower part of the drum. As it falls, it is sprayed with the feed melt or slurry.
- The coated granule is then lifted back to the fluidised bed, where the new surface layer solidifies by cooling or evaporation of its moisture content.
- The same cycle is repeated as many times as necessary until the desired grain size is achieved.

The falling curtain granulation process employs a granulator as a drum that rotates about its longitudinal axis, transporting the urea seeds through the granulator, with sprayers being present over a large part of the length of the drum for spraying the urea melt.

Spouted bed granulation

Toyo Engineering Corporation (TEC) was a pioneer of the spout bed urea granulator and has since improved the technology by developing the spout-fluid bed granulator. In the TEC process, the molten urea is fed on the spouting urea seeds through multi-spray nozzles to enlarge the recycle particles in the granulator. The water in the feed solution is evaporated by spouting air on the spouted beds in the granulator to produce the granules. The enlarged granules are cooled to a suitable temperature by fluidising air on the internal fluidised beds in the granulator. The falling curtain granulation process employs a granulator as a drum that rotates about its longitudinal axis, transporting the urea seeds through the granulator, with sprayers being present over a large part of the length of the drum for spraying the urea melt.

Process comparison

Table 1 compares the main process stages in urea prilling and granulation plants. Granulation units have more process steps than prilling towers. This means that granulation units have additional items of dynamic equipment, which require additional operational, maintenance and service expenses. (*Prills or granules?* **Nitrogen+Syngas** [No. 292, March-April 2008].)

Capital costs for a granulation unit are significantly higher than for prilling tower construction, by up to three times. Energy consumption is also higher, while granulation also requires the incorporation of a formaldehyde additive. Granular urea has traditionally commanded a premium in urea markets compared with prills, helping to offset the higher capital and operating costs, but the latter have remained popular in many markets, including the Middle East, Asia and Africa.

A prills revival?

While the most recently constructed and mostly export-oriented urea plants have adopted granulation technology, the leading Russian fertilizer technology company, JSC NIIK, has continued to develop prilling technology. NIIK has modernised the design of the prilling tower to enable urea producers to meet the highest standards of energy efficiency and low emissions, as well as supplying a prilled product of the highest quality.

NIIK has paid particular attention to the design and performance of prilling towers. Older-generation prilling towers were constructed from concrete and had a typical height of around 40 m. NIIK has developed a prilling tower with a composite structure, some 100 m high and 16 m wide, with a throughput capacity of between 600-2,100 t/d or more. The barrel of the tower can be made from either reinforced concrete or metals structure. The capacity for a new-generation single-line prilling tower is just below 3,000 t/d, though NIIK believes that this figure can be exceeded. The majority of urea production facilities of the Former Soviet Union are equipped with prilling towers built and revamped according to the designs of JSC NIIK.

The key features of NIIK's enhanced performance prilling tower are:

- A centrifugal sprayer with a vibrating priller located at the top of the tower permits the production of mono-dispersed urea with increased granule size.
- An injection-type scrubber with two in-line blocks that minimise ammonia and urea emissions before they are released into the atmosphere up to 40 mg/nm^3 and 10-25 mg/nm^3 respectively.
- An integrated prill fluidised bed unit that ensures product cooling to 50°C with minimal cracking or dusting.

On 5 June 2012, a new 1,500 t/d prilled urea plant designed by Stamicarbon with

Table 2: Urea prilling towers built and revamped by JSC NIIK 2000-date

Commissioning year	Location	Project	Capacity (t/d)
2005	Novomoskovsk, Russia	Revamp	1,200
2006/07	Novgorod, Russia	Revamp	1,500
2007	Salavat, Russia	Revamp	1,000
2010	Salavat, Russia	Revamp	1,200-1,400
2010	Fertalge, Algeria	New construction	1,200
2011	Nevinnomyssk, Russia	Revamp	1,500
2012	Cherepovets, Russia	Commissioning works and guarantee testing	1,500
2012/13	Novgorod, Russia	Revamp	2,000
2013	Novomoskovsk, Russia	Planned revamp	1,500
2013	Kemerovo, Russia	Planned revamp	1,700

a prilling tower designed by JSC NIIK was brought on stream at the PhosAgro Cherepovets Azot ammonia/urea site. The product parameters are as follows:

- Fraction content (<1 mm): 0.2-1.0%
- Fraction content (1-4 mm): 99.0-99.8%
- Fraction content (2-3 mm): 93.0-96.8%
- Granular strength: 0.9-1.0 kg/granule.

Table 2 lists recent JSC NIIK prilling tower references.

The pastillation alternative

Sandvik Process Systems has also addressed some of the issues relating to traditional prilling plants, many of which are now several decades old. For prill plants, high energy consumption, a lower product quality and dust and ammonia emissions are three key issues, arising from the cooling and crystallising against a large flow of upward-moving air. In some prilling plants, this air flow is created using fans; in others, natural draught is used. While the draught is created, the air becomes loaded with urea dust particles and ammonia, and is typically emitted into the atmosphere from the top of the prilling tower. (*A single solution to four challenges*. Mark Brouwer, UreaKnowHow, **Nitrogen+Syngas No. 313**. September/October 2011.)

In some cases, a dust scrubber is installed on top or alongside the prilling tower to reduce the urea dust emissions. The dust scrubber may in addition be combined with an acid washer to reduce the ammonia emissions. These scrubbers systems are only feasible in forced-draught prilling towers.

Increasing the load on a prilling tower can have negative consequences for prill quality. Higher moisture contents and higher temperatures cause more dust formation and an increased likelihood of caking problems.

Sandvik Process Systems have adapted its *Rotoform* pastillation system for use in prilling facilities. Fig.1 shows the basic flow-scheme. The feed to the *Rotoform* unit is urea melt with a 99.6 wt-% concentration and in existing plants can be branched off from the urea evaporation section, ahead of the urea melt pumps.

Urea melt is introduced under pressure in molten form to the drop-former. The *Rotoform HS* drop-former consists of a heated stator and a perforated rotating shell that turns concentrically around the stator to deposit drops of urea across the full width of the belt. The circumferential speed of the *Rotoform* unit is synchronised with the speed of the steel belt cooler, Fig 1: **Sandvik Rotoform pastillation process for urea**

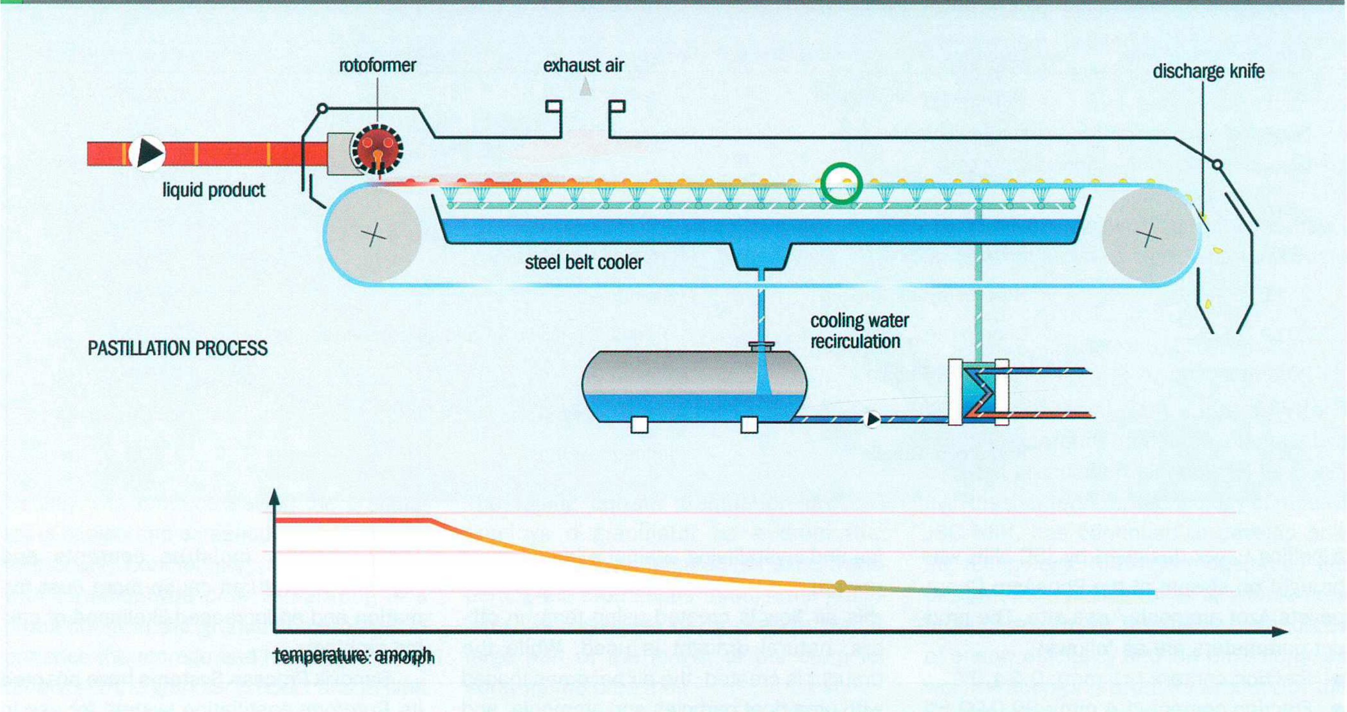
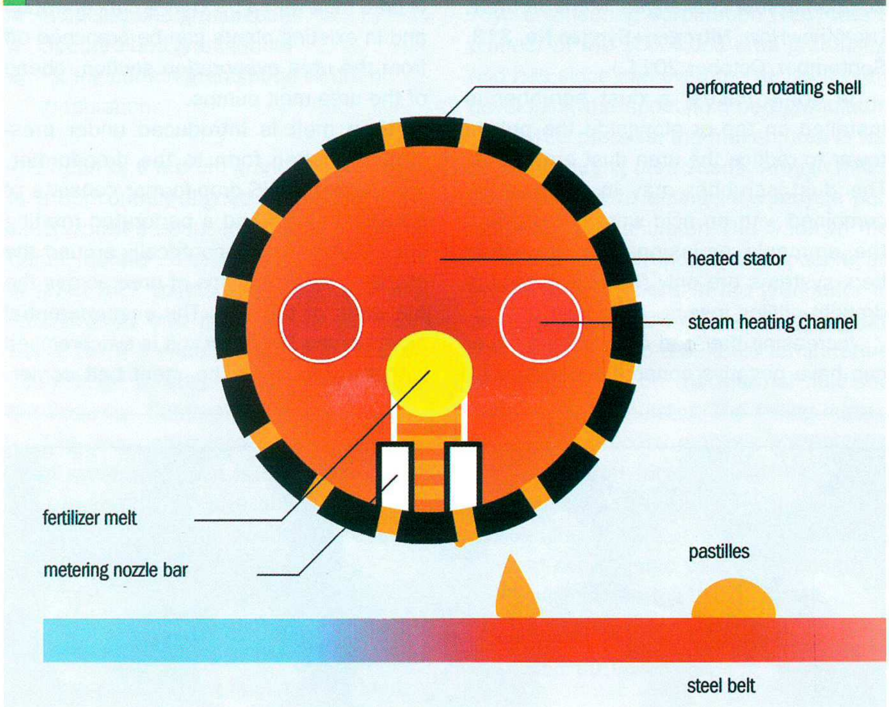


Fig 2: **Rotating shell delivers droplets of the required size**



ensuring that the drops are deposited on the belt without deformation and, after solidification, results in regular semi-spherical pastilles with an optimum shape.

The rotating shell (Fig. 2) contains rows of small holes which are sized to deliver the required product size. The heat released during crystallisation and cooling is transferred by the stainless steel belt to the cooling water of three cooling zones. These cooling zones are closed platforms, which contain the cooling water. This closed box absorbs the heat. The water is cooled in a cooling system (cooling tower) and returned to the *Rotoform* units. The Sandvik system eliminates the need to use formaldehyde to produce urea pastilles with a high crushing strength. The pastilles are very uniform.

After solidification, the pastilles are smoothly released from the steel belt via an oscillating scraper. The product then falls directly on to a conveyor belt for transfer to storage. An extra time period or handling stage is required for final hardening. The section above the moving steel belt is enclosed with a hood and vented to an existing vent system. This technology does not involve any large air flows and there is no visible urea dust emission. Any ammonia vapours produced are easily captured in a simple atmospheric absorber. Emissions of ammonia and urea are negligible.

By installing one or more *Rotoform* lines in parallel with a prilling tower, the load on the prilling tower will be reduced, leading to lower ammonia and urea dust emissions from the prilling tower and a higher prill quality. Power consumption is also reduced, by as much as 9 kWh/t per tonne of urea in the case of a forced draft prilling tower.

The quality of the semi-spherical pastilles is better than the quality of prills, and can even exceed the quality of granulated urea in certain aspects. Table 3 shows an overview of the product qualities of prills, granules and pastilles.

The strength is similar to granular product, even without any formaldehyde. The size of the *Rotoform* product is the same as for granules, moreover the size can be easily varied between 1 and 5 mm by exchanging the rotating shell. The pastilles are extremely uniform, even more than granules.

The *Rotoform* system with a typical capacity of 120-165 t/d or even 180 t/d can be used to produce a variety of speciality urea products in addition to fertilizer-grade urea, including technical urea for urea-formaldehyde (as used in *Ad Blue* fuel additives) and urea blended with micro- and macronutrients. The *Rotoform* system can also be used in the production of ammonium nitrate pastilles.

Agricultural urea in pastille form was first sold between January-May 2009 to farmers in Northern Germany. Local traders reported that the product was very well received. (*Sandvik: the Rotoform urea alternative*, **Fertilizer International**, No. 436 [May/June 2010].) Compared with prilled urea, farmers expressed a clear preference for *Rotoform* pastilles. Farmers' acceptance of urea pastilles was further evaluated after the crop harvest and was again reported to be very positive.

Sandvik Process Systems has recently upgraded its *Rotoform* technology, and in June 2012, the company launched the *Rotoform 4G* system. The latest 4G model comes with pneumatic functions that dispense with manual setting, making the system faster and easier to operate. Further design modifications facilitate faster and easier product changes. This results both in improved pastille quality and increased capacity and yields.

Granulation advances

The leading suppliers of granulation technology continue to upgrade the equipment and services they offer. In recent years, there have been notable improvements in urea finishing technologies, based on an enhanced understanding of the optimum methods to produce fertilizer granules for high product quality and lower dust and ammonia emissions. Cooling technology has also advanced, thereby reducing the risks of caking during storage. (*Better product quality*, **Nitrogen+Syngas**, No. 319 [September/October 2012].)

Stamicarbon, a global market leader in the development and licensing of urea technology, pioneered fluid bed granulation technology in 2002. This technology has been licensed in 18 urea plants, several of which exceed 3,500 t/d in capacity. At the heart of the Stamicarbon process is the film spraying characteristic of the nozzles.

Table 3: **Comparable product properties of urea prills, granules and pastilles**

	Prills	Granules	Pastilles
Average diameter (mm)	1.5-1.9	2.0-4.0	2.0-2.5
Moisture (wt-%)	0.15-0.30	0.10	0.10
Formaldehyde content (wt-%)	0.1-0.3	0.30-0.55	Only when required
Shape	Spherical	Spherical	Hamburger
Crushing strength (N)	12 (1.7 mm)	30-40 (3 mm)	15-75 (3 mm)
Product temperature (°C)	60-80	40-45	40-45

Source: Brouwer

This spraying method requires a minimum amount of formaldehyde and reduces the amount of dust.

Stamicarbon has addressed the issue of dust formation in urea granulation. Regular shutdown for flushing the granulator is needed to ensure reliable operation, and the run-time between granulator washings can reach about three months. The formation of dust can never be entirely eliminated, and in a fluid bed granulation plant, this can arise from attrition, the overspray of nozzles, the crusher and desublimation.

Stamicarbon has optimised the design of the granulator with the target of reducing the size of the granulator casing. The second-generation fluid bed granulator was modified as follows:

- No slopes in the side wall
- Disengagement height reduced to 4 m
- Air outlet in line with the length of the granulator above the cooling zone.

The next optimisation was to design the granulator air outlet above the recycle line in the front wall of the first granulation compartment. Stamicarbon examined the effect of these modifications with CFD calculations.

The relocation of the air outlet to the inlet part of the granulator has the effect of reducing the dust concentrations to only a very limited area of the granulator above the recycle port. The residence time of the dust is minimised. These improvements ensure longer run times compared with the first-generation fluid bed granulator design.

Casale's Vortex® design

Urea Casale has developed a new process for large-scale urea granulation. This process employs a rotating fluidised bed and an innovative design of spray nozzles. (Fig. 3) This makes it possible to operate the granulator in a once-through mode, producing on-size fraction in the granulator itself and eliminating the need to recycle off-size material. The Casale *Vortex*® granulator is also suitable for revamping finishing units and can be used through the fattening approach to debottleneck existing prilling towers to increase capacity or to improve product quality.

In the *Vortex* rotating fluid bed, the particles are fluidised with air fed from the bottom through a grid, but in contrast with other fluid bed designs, the fluidised particles have two types of motion:

- The longitudinal motion typical of all fluid beds used for granulation
- A circular motion that generates two vortex eddies.

The rotating motion of the particles obtained in the *Vortex* granulator allows better control of the spraying of the melt urea on the particles of the bed. Urea melt is sprayed into the rotating fluid bed from the side, and not from the bottom (as is the case with earlier technologies). In this way, the wetting and the solidification processes are very regular and controlled. The cycle is repeated many times while the particles follow the circular paths of the vortex, consisting of two steps:

- Wetting the particles with new melt as they reach the position of the lateral spraying nozzles
- Solidification and cooling of the newly deposited melt as it follows the rest of the path.

The side location of the spray nozzles allows their substitution for cleaning purposes during plant operations. The growing granules move along the length of the *Vortex* granulator with a plug flow motion. In the course of this longitudinal motion, the seed is slowly enlarged and the particles reach the desired size. Growth of the granules is very uniform and the final product has an excellent size distribution.

Fig 3: **Vortex® granulator**

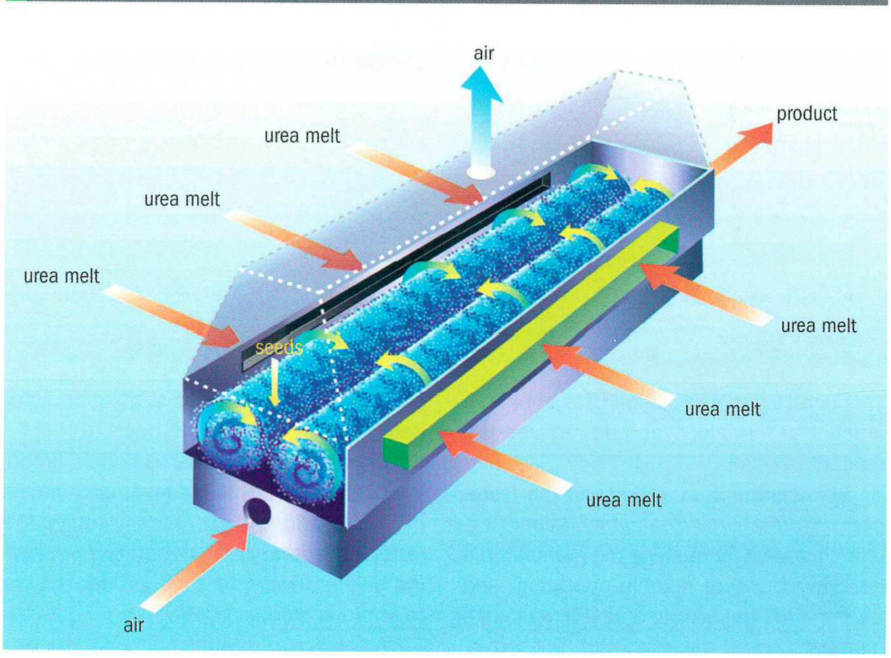


Fig 4: **Spraying nozzle**

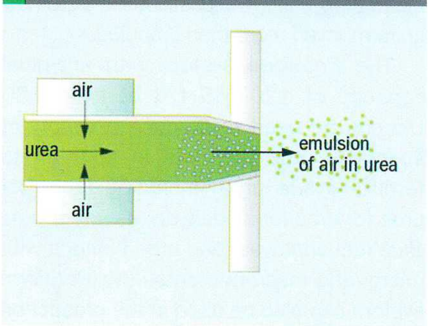
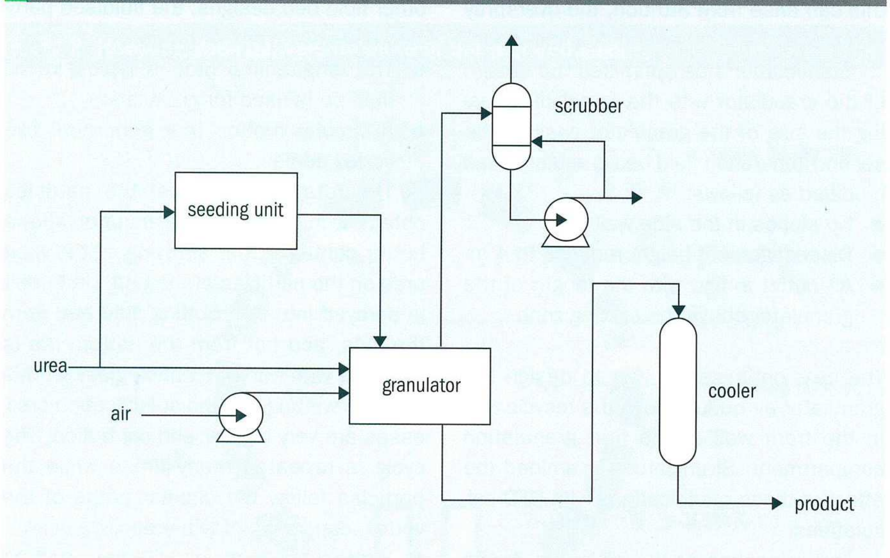


Fig 5: **Vortex® granulation plant**



The melt urea is sprayed into the bed, using innovative nozzles developed by Casale. The main function of the nozzle in the granulation process is to produce small droplets or a thin film of urea melt in order to deposit the right amount of melt on the growing granules. Casale has chosen to operate the *Vortex* granulator with a 96% urea solution, so it is important that the nozzle generates very small droplets in order to guarantee the proper evaporation of the 4% water contained in the solution. The Casale nozzle design generates very small droplets through the formation of an emulsion of air in urea, which is then sprayed out of the nozzle.

As shown in Fig. 4, in the nozzle air is injected into the jet of melt, generating a multitude of small bubbles (emulsion). The air present in the emulsion breaks the emulsion jet exiting the nozzle into the very small liquid droplets that are required to achieve perfect granulation. The advantage of the concept is the amount of air required for the nozzles to generate the very small bubbles is very low, thus saving a significant amount of compression energy.

The rest of the Casale installation is much simplified. In particular, none of the equipment for handling the off-size material (screening, crushing, recycle converters) is required. The seeds for the granulator are generated in a dedicated seeding unit, producing particles that are so uniformly sized that the product exiting the granulator is already on-spec. Fig. 5 shows the simple one-through configuration.

One notable feature of the Casale *Vortex* granulator is the modular design, which standardises the size of the eddies and enables units of different capacities to be designed simply by varying the length of the granulator and number of eddies.

The consumption of utilities is mainly the consumption of electric power, at 22 kWh/t. Dust emissions from the granulator are also fairly low, so the amount of urea (as 100%) recycle is only 2% of the total production. Proper selection the scrubbing system guarantees values of urea in the exhaust air of no than 20 mg/Nm^3.

Casale's first reference is for a *Vortex* granulator that has been built in Russia to debottleneck an existing prilling tower and improve the product quality. The unit has the capacity to produce 2,000 t/d of "super-prill" product. A similar unit is under construction in China to debottleneck the existing prilling tower from 1,740 t/d to 2,610 t/d.

The *Vortex* granulation unit has improved the quality of the prills produced in the existing prilling tower, making them 15% bigger in diameter and harder, with 40% higher crushing strength.

The advantages of the *Vortex* granulation technology, confirmed by the first application, may be summed up as follows:

- Simple plant operation (no recycle)
- Extremely short start-ups (no recycle)
- Uniform product distribution (the granules all grow at the same rate)
- High product quality
- High flexibility in operation.

These developments confirm that urea producers enjoy a wide range of choice when selecting the appropriate product finishing technology.