

## **VortexÒ granulation: The new route to high-quality solid nitrogen fertilizers**

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**Abstract**

***Since the start of its activity, UREA CASALE has developed several innovative technologies for the revamping of urea plants and more recently also for the design of new ones.***

***With the application of these technologies, CASALE has been able to revamp 110 plants in the last 25 years achieving considerable increase in plant efficiencies and capacities, and gaining a leading position in urea plant revamping.***

***Moreover, CASALE has also recently designed and commissioned a grass-root plant.***

***In order to enhance its technological portfolio into an area of big importance for both revamping and new plant design, UREA CASALE has developed a new process for large-scale granulation of urea.***

***This process differs from the dominant fluidized-bed granulation processes in using a rotating fluidized bed and spray nozzles of innovative design.***

***This results in possibility to operate the granulator in a once-through mode producing on-size fraction in the granulator itself, eliminating the need to recycle off-size material.***

***This paper presents the new CASALE technology describing its application to the design of new units and also to revamping of existing ones.***

***The paper gives also a description of the first industrial application of this technology.***

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## 1. INTRODUCTION

**UREA CASALE S.A.**, established in 1991 to carry on the urea technology activities started by AMMONIA CASALE S.A. in 1985, is the company of the CASALE group active in the field of urea.

Since the beginning, efforts were mainly directed to the revamping of existing plants, with almost 90 plants being revamped since 1985.

Through its revamping activities and thanks to its capability of developing innovative technologies, UREA CASALE was able to become, in a very short time, a leader in urea plant revamping, having its own technologies to upgrade all types of urea plants and acquiring a considerable share of the market.

Energy consumption, capacity increase, corrosion control, pollution abatement and product quality are the key areas for upgrading plant performance.

All the technological experience matured with the revamping activity, led also to the development of a new improved process for the design of grass-root plants.

Utilizing its proprietary technology, UREA CASALE has successfully revamped several urea plants and designed a grass-root one.

Like the other companies of the CASALE GROUP, the main strength of UREA CASALE lies in licensing its technologies. A team of very specialized and experienced people develops, therefore, most of the technologies in-house.

UREA CASALE Technical Services avail themselves of the right specialists and of advanced tools for investigating, analyzing and picturing complex phenomena, including such tools as computer-aided techniques with applications ranging from chemical process design to fluid dynamics evaluations.

Following the trend set by AMMONIA CASALE, UREA CASALE invested and is still significantly investing in technology development, putting also a lot of effort into developing the right process design tools.

One of the most recent developed technologies is the Vortex® Granulator, which is described in this paper and is a typical example of how the combination of above mentioned tools and expertise could lead to the development of innovative concepts.

While approaching the development of technologies for the design of grass-root plant, CASALE realized the importance of owning also technologies for the solidification part of the urea plant and started a development program for a new granulation technology, which is the mostly used technology in grass-root plants.

As its main strength is the revamping of existing urea plants, UREA CASALE steered the development so that the new technology could be also conveniently used for debottlenecking existing units, especially prilling towers.

Using its technological portfolio, CASALE was, in fact, able to achieve very large capacity increases in the wet part of the plant, and it was hard to take it up with the solidification part of the plant.

The result was a technology that enables UREA CASALE to design very competitive granulation units for grass-root plants but also to debottleneck existing prilling towers for large capacity increases.

The above development was achieved combining CASALE deep knowledge of fluid dynamics processes with its specific know-how of the chemical and physical-chemical aspects of the urea process.

## 2. VORTEX® GRANULATION TECHNOLOGY

The Vortex® Granulation developed by UREA CASALE is an innovative granulation technology based on the fluid bed technology.

The Vortex® Granulation combines the advantages of the fluid bed granulation technology with the ones of the drum granulation.

The features of the Vortex® Granulation are the following:

- low energy consumption
- minimum use of formaldehyde
- high product quality
- low investment
- high flexibility in the production
- wide range of application including prilling tower revamping

This technology can also be conveniently used to debottleneck existing prilling towers for capacity enhancing and quality improvement.

### 2.1 Technical Description

The two main characterizing elements of the Vortex® granulation technology are:

- the Vortex® granulator
- the Spraying nozzles

#### **Vortex® Granulator**

The Vortex® granulator, which is the core of the Vortex® granulation technology, is a rotating fluid bed.

In this rotating fluid bed the particles are fluidized with air fed from the bottom through a grid but, differently to any other fluid bed used for granulation, the fluidized particles have two types of motion:

- The longitudinal motion typical of all fluid beds used for granulation.
- A circular motion that generates two eddies (Vortex) characteristic of the Vortex® rotating fluid bed.

This principle is shown in figure 1.

The rotating motion of the particles obtained in the Vortex® granulator is somewhat similar to the motion obtained in drum granulators and allows to have a better control of the spraying of melt on the particle particles in the bed.

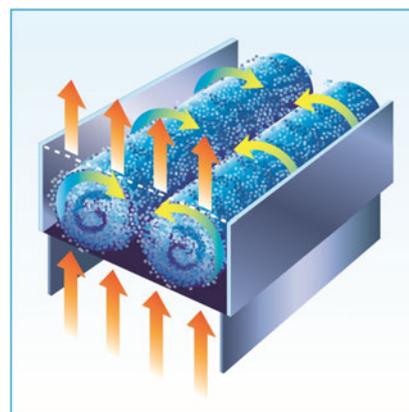


Fig. 1 – Rotating fluid bed

Urea melt (L) is, in fact, sprayed into the rotating fluid bed from the side, as shown in the figure 2, and not from the bottom as in state of the art technologies.

In this way the wetting and solidification processes of the growing particles follows a cycle that is very regular and controlled. The cycle is repeated many times while the particles are following the circular paths of the vortex and consists of two steps;

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

The growing granules are moving along the length of the Vortex® granulator with a plug flow motion, from one end, where the seeds (S) are introduced, to the opposite end where the product (P) is taken out.

During this longitudinal motion, the growing particles undergo many of the cycles mentioned above so that the seed are slowly enlarged and reaches the final desired size.

As the melt is sprayed very uniformly all along the length of the granulator, a uniform growth of the granule is achieved and the final product has a size distribution equal or better than the seeds.

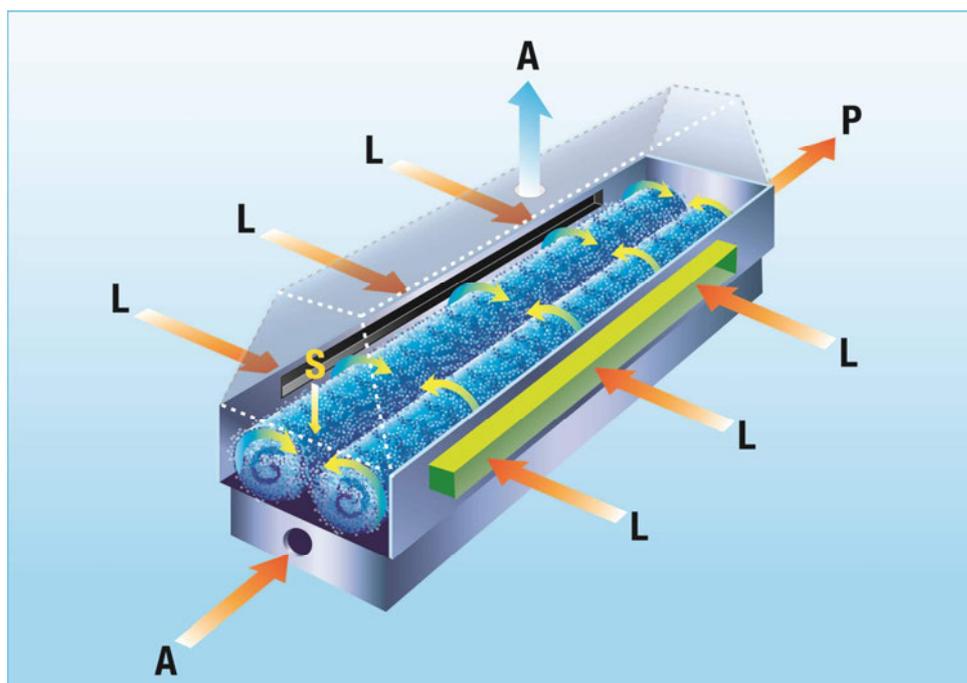


Fig. 2 – Vortex® granulator

### Spraying nozzles

Melt urea is sprayed into the fluid 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.

As CASALE has chosen to operate the Vortex® granulator with 96% urea solution, it is important that the nozzle will generate very small droplets in order to guarantee the proper evaporation of the 4% water contained in the solution.

The innovative concept of the nozzle is that the very small droplets are generated through the formation of an emulsion of air in urea, which is then sprayed out of the nozzle.

As shown in figure 3, 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 obtain a perfect granulation.

The advantage of this concept is that the amount of air required for the nozzles to generate the very small bubbles is very low with a significant saving of compression energy.

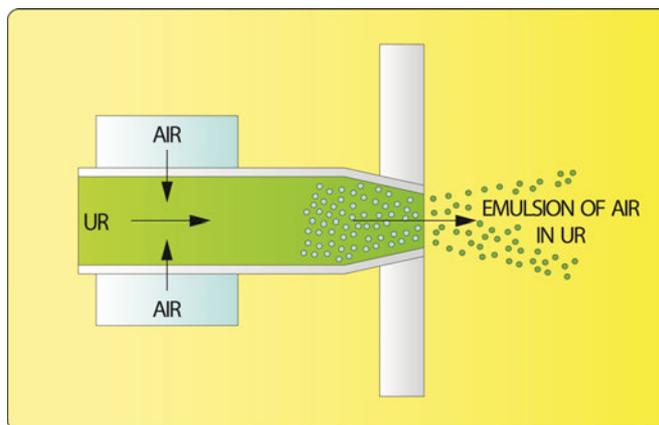


Fig. 3 – Spraying Nozzle

### The Vortex® granulation unit

Thanks to the fact that the growth of the seeds entering the Vortex® granulator is very uniform and constant, it is possible to design granulation units, based on the Vortex® granulator, which are very simple.

In particular it is possible to eliminate the screening, crushing and recycle of the oversized and undersized exiting the granulator.

In the Vortex® granulation plant a seeding unit is generating the seeds for the granulator. The seeds are generated with a very uniform distribution and the product exiting the granulator is already on-spec.

Air is blown into the bottom of the granulator to fluidize the particle and to generate the rotation. Air is also blown into the nozzle to generate the above-mentioned emulsion and

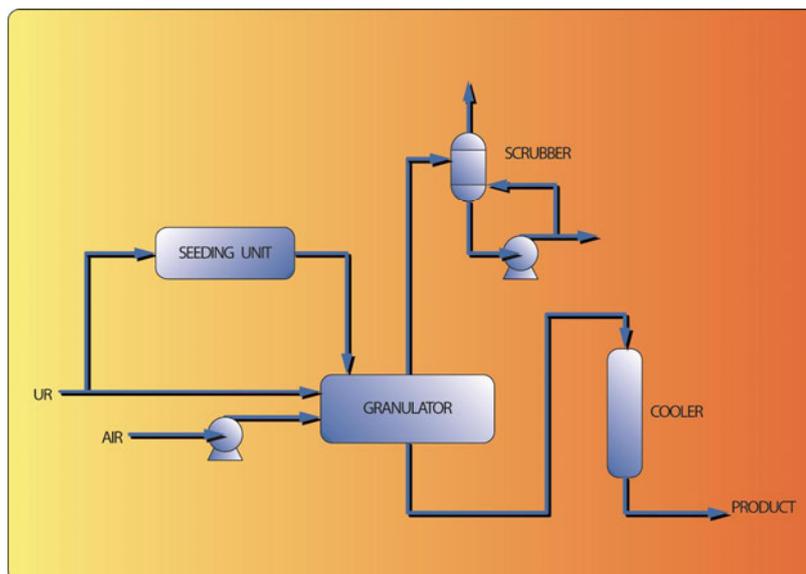
around the nozzles to protect the jets of droplets.

The air exiting the granulator is sent to a scrubbing unit to eliminate the dust and, if required, also ammonia. Proper care is given to the selection of the scrubbing design in order to guarantee the elimination of urea down to the allowable levels.

The product exiting the granulator is sent to a solid cooler for the final cooling.

The

Vortex®



granulation plant has, therefore, a once-through configuration becoming very simple, as shown in figure 4.

One other important feature of the Vortex® granulation technology is that the Vortex® granulator is designed to be modular as the size of the eddies is standardized. In this way, units of different capacity can be designed just by varying the length of the granulator and the number of the eddies.

It is, therefore, possible to design large granulation plants with minimal scale-up risks.

Fig. 4 – Vortex® granulation plant

The plant becomes also very compact as shown in the 3D model shown in figure 5.

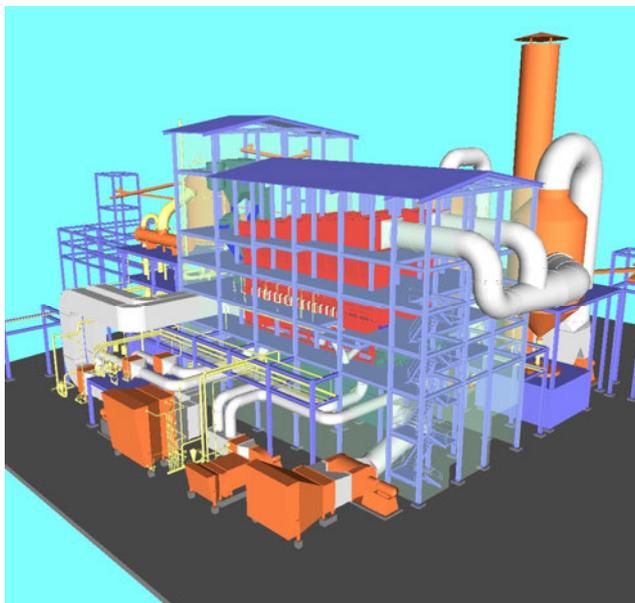


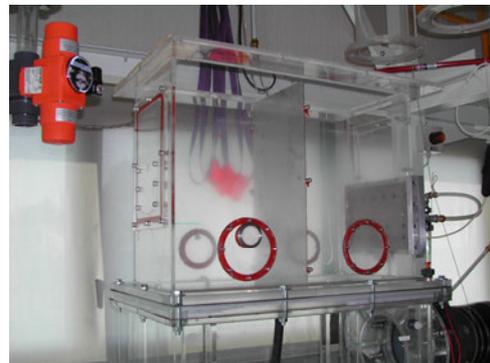
Fig. 5 – 3D model of Vortex® granulation plant

## 2.2 Development of the Technology

CASALE has developed the technology with a two-step program involving the construction the following two pilot units:

- A dry pilot unit working with only air and plastic spheres (or urea granules);
- A pilot unit operating with urea melt obtained by melting urea prills or granules.

With the first unit, CASALE has developed the rotating fluid bed concept and studied its fluid dynamic behavior identifying also all the parameter characterizing this type of fluid bed.





lot unit



With the second unit, CASALE has completed the development of the technology. With this unit it was possible to simulate the behavior of an industrial unit, operating with the same conditions.

This second unit has a granulator with a size that is in 1 to 1 scale, for what the cross section is concerned, with future industrial units that will be just longer.

The pilot unit is a batch unit and has an equivalent capacity of 30-40 MTD. Running tests with different durations will simulate the operation in full-scale units of different size.

With this second unit CASALE was able to produce all the different products size and types. This allowed to fully develop the new technology with both 99.7% urea melt and 96% urea solution as feed stock, determining all key parameters to produce top quality product.

After the full development program carried out with the pilot unit, Casale was in a position to design the first industrial granulation unit. More detail about this first industrial unit will be given in a later section of this paper.

Fig. 7 – Pilot unit

### 2.3 Performances

With the Vortex® granulation the following quality of the product is obtained:

- Total Nitrogen	46.3 w%
- Moisture	0.2 w%
- Biuret	0.7-0.8 w%
- Formaldehyde	0.25 w%
- Distribution 2-4 mm	> 95 %
- Hardness (on 3 mm)	4 kgf

The consumption of utilities is mainly the consumption of electric power, which is as follows:

- Electric power consumption	22 kWh/MT
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The dust emission from the granulator is also fairly low so that the amount of urea (as 100%) recycle is only 2% of the total production.

The proper selection of the scrubbing system would guarantee to obtain values of urea in the air exhausts of 20 ppm.

As shown in figure 8, the product produced from the Vortex® granulator has a very compact crystal structure typical of the granular product.

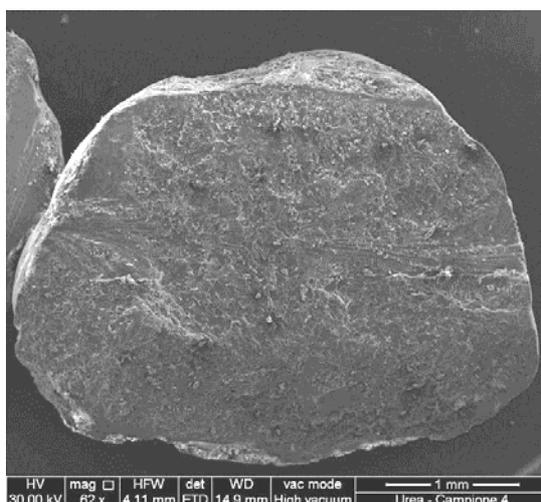


Fig. 8 – Cristal structure of a granule

The advantages of the Vortex® granulation technology can be summarized as follows:

- Simpler plant operation – (no recycle)
- Extremely short start-ups – (no recycle)
- Lower maintenance costs
- Lower operating costs – (low energy consumption, use of 96% urea solution, low formaldehyde content, low dust emission from the granulator)
- Uniform product distribution – (the granules are all growing in the same way thanks to Vortex® design)
- Low investment (simpler plant)
- High flexibility in operation

### 3. APPLICATION OF VORTEX® GRANULATION TECHNOLOGY TO PLANT REVAMPING

When considering urea plant revamping projects, often the prilling tower becomes a bottleneck limiting the capacity of the plant and/or making difficult to deliver a product of good quality.

Using the Vortex® granulation technology, it is possible to debottleneck existing prilling towers in order to overcome this problem.

In order to debottleneck the prilling tower to reach high capacity increases and also to improve the product quality, CASALE suggests installing a small Vortex® granulation unit in parallel with the prilling tower.

The urea melt produced in the plant will be split sending part to the existing prilling tower and the rest to the new unit, which would treat all the prills coming from the prilling tower.

Generally, the existing prilling tower will be loaded with basically the same amount of melt as before the revamping with eventually just some minor increase. The additional melt is then treated in the parallel granulation unit.

The new parallel granulation unit enlarges the prills coming from the prilling tower, which are sent to the granulator as seeds, to super prills.

An on-spec product is obtained with no need for screening crushing and recycling.

The figure 9 is showing the proposed arrangement.

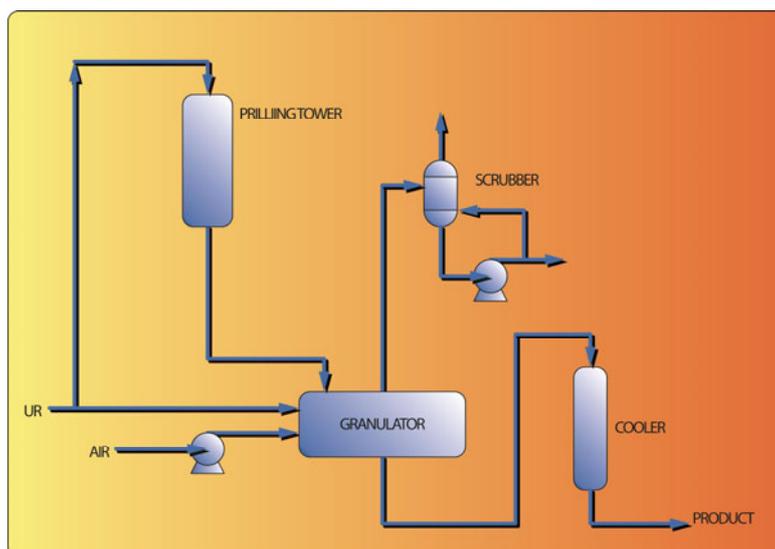


Fig. 9 – Prilling tower debottleneck with Vortex® granulator

The size of the final product can be optimized according to the client needs.

Adjusting the size of the prills produced in the existing tower it is possible to produce super prills of the same size of the prills produced before the modification or even of bigger size, following the request of the client.

The super prills will feature higher quality than the prills produced before with less dust, high crushing strength and lower temperature.

Using the above described approach, and thanks to the fairly compact size of the Vortex granulator (see figure 10), the capacity of existing prilling towers can be drastically increased in a very convenient way.

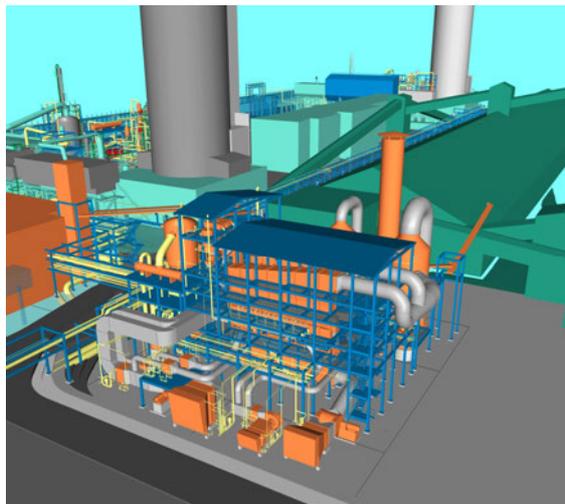


Fig. 10 – 3D model of Prilling tower debottleneck with Vortex® granulator

#### 4. FIRST INDUSTRIAL APPLICATION

CASALE has recently designed one Vortex® granulation unit that has been built in Russia to debottleneck an existing prilling tower.

The unit has a capacity of 500 MTD and is designed to receive 1'500 MTD of prills as seeds to produce 2'000 MTD of final super prill product.

Presently, as the revamping of the solution part of the plant is not completed yet, the unit is operated with 900 MTD of prills as seeds producing 1'400 MTD of final super prill product.



Fig. 11 - Vortex® granulation plant in Russia

The operation of the plant has proven also on an industrial scale the validity of the Vortex® granulation technology, including the validity of the once-through operating mode.

As expected, the Vortex® granulation unit improves the quality of the prills produced in the existing prilling tower making them:

- Courser (15% bigger diameter)
- Harder (20% higher crushing strength)
- Producing less dust in the warehouse (30% less dust formation)

Figure 12 shows e microscope picture of the produced super prill. In the picture it is possible to see clearly the external skin of the super prill with the typical compact structure of a granular product.

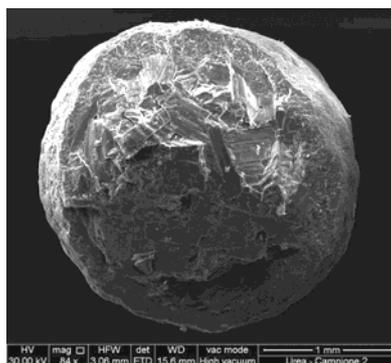


Fig. 12 – Structure of a super prill

By reducing the quantity of prills sent as seeds into the granulator, some tests have also been successfully carried out in this unit to simulate the production of particles of the size equivalent to the ones of a granular product (3 mm average diameter, 2-4 mm fraction > 95%).

## 5. CONCLUSIONS

Since the beginning of its history, UREA CASALE has been able to develop various technologies and concepts that have brought a significant step ahead in the urea industry.

The recent development of the Vortex® granulation was, again, a good example of how the combination of ideas/expertise with modeling and research capabilities could lead to the development of innovative technologies.

The Vortex® granulation offers to the industry a very efficient process for the construction of new granulation units.

The new Vortex® granulation design has proven to be also a very powerful tool to debottleneck existing prilling towers, and offers to the owner of such plants a very convenient way to increase their capacity improving the product quality.