UPGRADING A NON-STAMICARBON GRANULATION PLANT

STAMICARBON

NEXTCHEM
MAIRE Sustainable Technology Solutions

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SUMMARY

ABSTRACT

Stamicarbon's granulation technology demonstrates unprecedented continuous running times, exceeding a worldwide average of 90 days before requiring a wash. In some cases, uninterrupted operation has exceeded 125 days and even reached up to 215 days. This performance is achieved due to reduced dust formation by applying film spray nozzles. Such extended run length, together with significantly lower formaldehyde usage, enhances efficiency and productivity of granules, making this process a highly reliable and cost-effective solution for urea finishing.

In response to numerous client requests, Stamicarbon has developed a revamp design to transform atomization granulators into film spraying units. Milestones include the development of a scaled-up film spray nozzle reaching up to atomization capacity (including design margin), successfully tested at pilot scale, and a tailor-made process concept that unlocks the full potential of non-Stamicarbon granulators.

DEVELOPMENT OF LARGE-CAPACITY FILM NOZZLE

1 INTRODUCTION

Stamicarbon, the nitrogen technology licensor of NEXTCHEM (MAIRE Group), has established market leadership in urea fluidized bed granulation technology over the past two decades, demonstrating clear technical and commercial advantages over competitors. The film spraying concept offers two key benefits: reduced formaldehyde consumption and extended continuous production, resulting in significant cost savings. Such advantages have historically prompted urea producers to revamp their facilities to Stamicarbon's. In fact, Stamicarbon's first granulation plants were based on those revamps.

Although plant revamps require investment and temporary shutdowns, Stamicarbon has developed technical solutions to minimize modification costs and downtime, consistently achieving a payback period of two to three years.

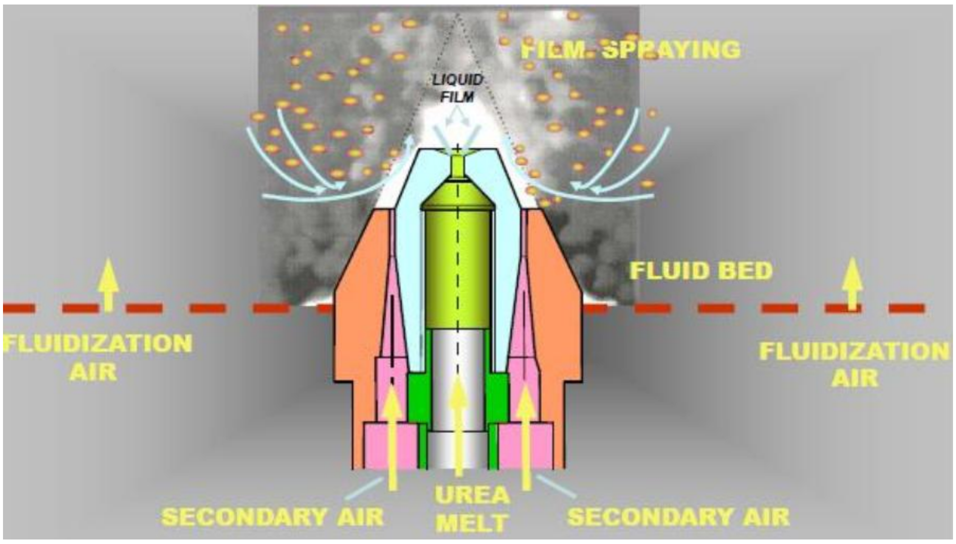
Revamp efforts focus on converting atomizing nozzle-based granulators (used by major competitors) to Stamicarbon's film spraying systems. These plants differ technically from the Stamicarbon design in the following main parameters:

1. Capacity of the spraying nozzle is 2-2.5 higher than the Stamicarbon's film spraying nozzle, requiring considerable redesign of the headers in case of a revamp.
2. Water concentration in the urea melt solution entering the granulator is 3-4%w instead of 1.5%w, requiring additional heat of crystallization to be removed in the granulator.

This paper describes the developments made by Stamicarbon to close the gap with alternative designs while minimizing investment and maintaining the unmatchable performance of its granulators. This involved, among other innovations, the design of a patented film spraying nozzle that can deliver the necessary capacity at the operating conditions of competitor plants. At the same time, it matches the required water content in the melt and compensates for the extra heat of crystallization needed due to reduced heat of water vaporization from the melt.

2 HIGH-CAPACITY FILM SPRAYING

Stamicarbon, with over 50 years of expertise in granulation science, has developed a revamp design that converts atomization granulators into film spraying – the core of Stamicarbon's granulation technology. This method's success lies in the layering process achieved after high-speed secondary air sucks in seed particles from the fluid bed and directs them toward a cone film, allowing each pass to build up layers of melt on their surfaces (Figure 1.A). Before a new layer of liquid melt is applied to the seed particle, the layer on the particle is completely solidified in the bulk of the fluidized bed and cooled by fluidization air (Figure 1.B).



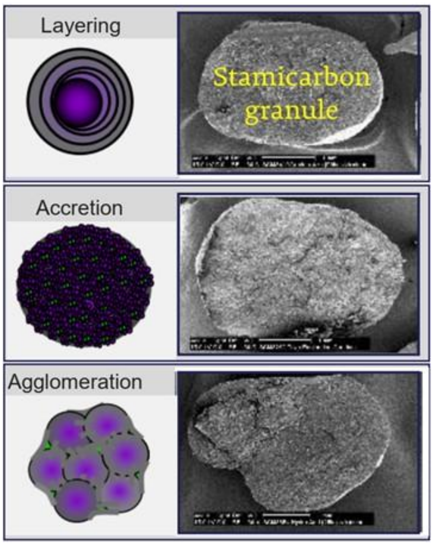


Figure 1.A: Film spraying process.

Figure 1.B: Layering vs. other mechanisms.

2.1 Mechanism of cone film formation

Scaling up the Stamicarbon standard granulation nozzle from current capacity to competitor's and revamp cases requires a deep understanding of the film spray mechanism. The process involves the following key steps:

1. A urea melt swirl develops inside the nozzle and exits the tip with a discharge angle leading to a fine cone-shaped film.
2. The film becomes thinner as it progresses upwards (Figure 2.A) and increases in turbulence. If left alone, it would reach a disintegration point into droplets at a certain length (Figure 2.B).

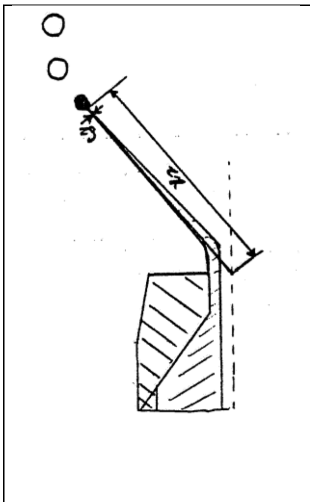


Figure 2.A: Edge contraction.

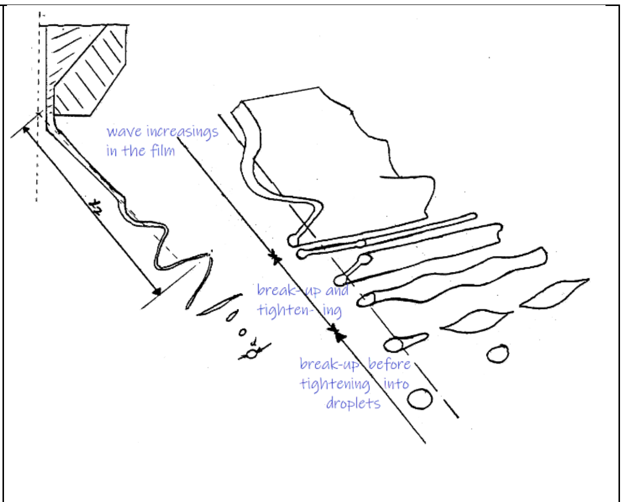


Figure 2.B: Aerodynamic wave formation.

3. Secondary (2ry) air intersects the film prior to (self-)disintegration, maintaining a straight and firm melt cone below the intersection point.
4. The layering process occurs by exposing the granules drawn into the film by the vacuum zone generated by the 2ry air, which comes next to the melt flow, entering from the collar.

This sequence suggests that spray angle, film thickness, intersection height of the urea melt with the 2ry air stream, as well as melt and 2ry air velocity/flow, are the key parameters governing the process. The question is: how to set up adequate target parameters and mold the system to reach them?

2.2 Scale-up criteria and CFD of urea melt nozzle performance

A scale-up strategy was built and patented using Stamicarbon's standard nozzle as a basis.

Stamicarbon, together with its sprayer supplier, conducted CFD simulations in an iterative approach, in which input variables (mainly geometry) were incrementally modified aiming to meet the target scale-up criteria. Several CFD simulations of the urea melt flow fluid (without 2ry air, see Figure 3.A) were sufficient to achieve the same film thickness and area to mass flow ratio of urea melt at an equal intersection with the 2ry air for the desired atomization capacity (see Figure 3.B). This led to a proprietary nozzle design delivering a more open spray angle and requiring only a ca. 35% increase in urea melt pressure to duplicate its capacity.

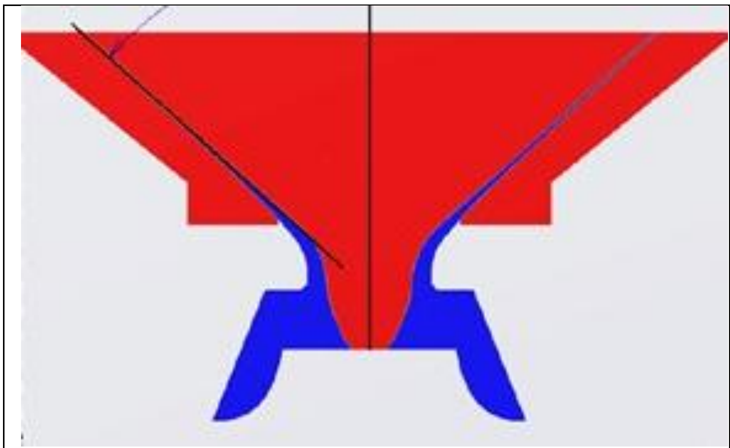


Figure 3.A: Spray angle without 2ry air.

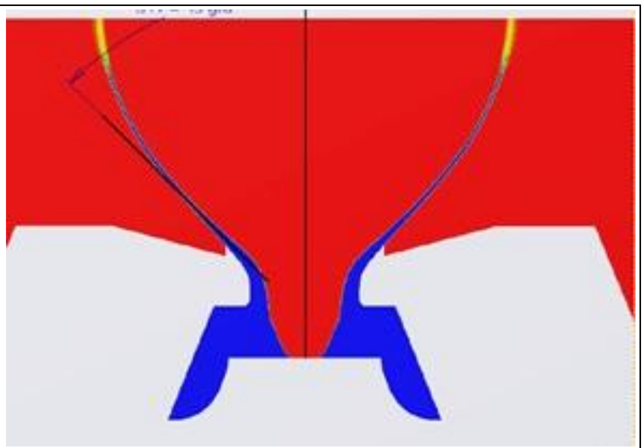


Figure 3.B: Spray angle with 2ry air.

2.2.1 CFD of combined hollow melt cone and air ring

In the next step, the air ring was engineered and checked with a CFD simulation that combined both the urea melt flow and the 2ry air, so its interaction was studied. In summary, it was proven that after geometric modification of the large-capacity nozzle the following criteria were met:

- Reached target 2ry air flowrate with ca. 10% lower pressure drop than the reference nozzle.
- Reached the same air velocity of 2ry air at urea contact point (see Figures 4.A and 4.B).
- Reached an air film radius at contact height fitting well with the scale-up criteria.

It was also confirmed that the spray angle was only slightly reduced once the 2ry air was introduced.

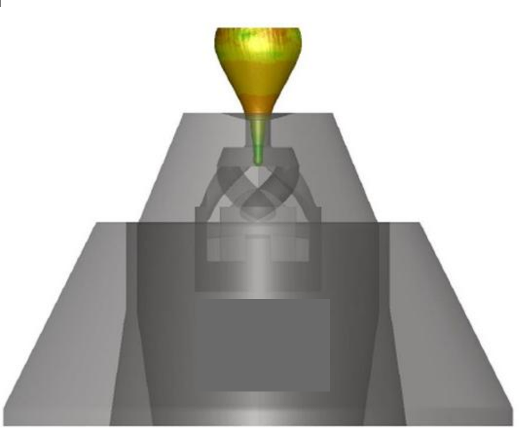
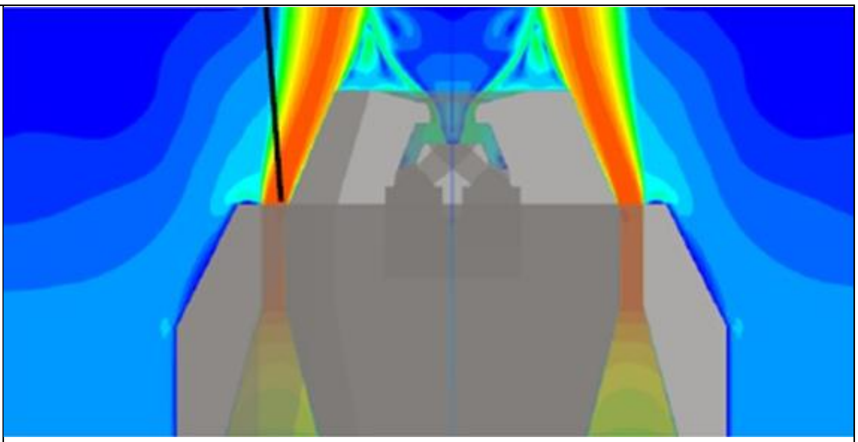
	

Figure 4.A: Velocity contour of urea melt with 2ry air.	*Figure 4.B: Velocity of the 2ry air in the ring gap is calculated to be 270 m/s.*

Moreover, the new design revealed the following mechanical practicalities:

- The front head diameter of the large-capacity nozzle became somewhat larger, so it requires a different screwing tool since the grooves are located at a larger distance. Otherwise, the diffuser of the new design would be affected. The total nozzle length is the same as the reference.
- The standard Stamicarbon thread connection was part of the design for prototyping, but it will be custom-engineered for commercial production. The exact thread will be discussed on a case-by-case basis with the end user.

2.2.2 Prototype & water tests

In this and subsequent sections, "droplet(s)" refers to urea melt droplets emerging from the layering process and causing dust buildup in the granulator. To get an indication of dust buildup, Stamicarbon requested its supplier to build a prototype and execute water tests to confirm a similar droplet size between the reference and large-capacity nozzles. The reason behind the comparison is the expected main mechanism of dust formation: airborne dispersion and adhesion of fine melt particles. These include melt droplets that fly outside the bulk of the fluid bed due to its smaller size and collide with a surface, where they build up as fouling. Thus, ensuring that the new nozzle will not generate finer droplets than the standard will prove that it will lead to, at maximum, the same dust generation and carryover. This will eventually ensure that the same run length between washings is achieved. Additionally, the parameters predicted by CFD, such as the pressure drop, shape of the nozzle cone, approximately the same intersection point of air to water, etc., were partially confirmed (bearing in mind that the sprayed fluids differ in properties).

The Sauter mean diameter (d32) was used as the parameter to compare both droplet distributions. Histograms of droplet size achieved with 2ry air revealed that the large-capacity nozzle generates droplets of equal or slightly larger size (probed by rigorous statistical hypothesis testing). This suggests that predicted dust generation is similar or lower, confirming the success of the scale-up criteria.

2.2.3 Pilot test results

A pilot plant campaign was executed in (Figure 5) to evaluate the differences in performance between the large-capacity nozzle and the standard one in terms of dust generation and final product properties.

During the campaign, the standard nozzle was tested at both standard design and revamp capacities. The first scenario corresponds to the design case of Stamicarbon's granulation plants, while the latter provides higher load expected after increased capacity, washing activities, etc. The large-capacity nozzle was tested at three different melt loads, corresponding to design and capacity increase cases (including specific operations, such as after-washing, etc.). Composition of the melt feed was kept as close as possible to commercial Stamicarbon granulation plants.

Figure 5: Pilot granulator.

Dust generation

The first element of comparison was based on dust generation. This is defined as the combined amount of dust captured at periodic intervals in both the cyclone downstream the granulator and its off-gas. The former was measured gravimetrically, regularly weighing the dust captured at the bottom of the cyclone, while the latter was an isokinetic measurement by a specialized analytics company. The dust generated in the crusher was subtracted from the amount to isolate the contribution of the nozzle.

Mean dust formation using the standard and large-capacity nozzles was statistically the same – given the variance or standard deviation – both falling well on the low side of the commercial plant expectation (2.8-4%w). Therefore, the large-capacity nozzle demonstrates comparable performance to the standard nozzle in terms of dust generation.

Final product properties

At the beginning of each dust measurement, the following streams were sampled at the same time and analyzed onsite for particle size distribution (PSD) and offsite for composition (biuret and formaldehyde) and properties (crushing strength and caking tendency):

- Granules from the outlet of the granulator,
- Coarse and fine recycle streams after sieving,
- Crushed recycle, and
- Final product.

Biuret and water

Biuret and water concentrations were confirmed to be equal after respective corrections of residence time (coming from the different capacity of the tests) and water sources (coming from formaldehyde addition).

Formaldehyde

The mean formaldehyde content (%w) for the standard and large-capacity nozzles is shown in Figure 6 below, indicating no difference, with both nozzles meeting the expected 0.3%w of the commercial plant.

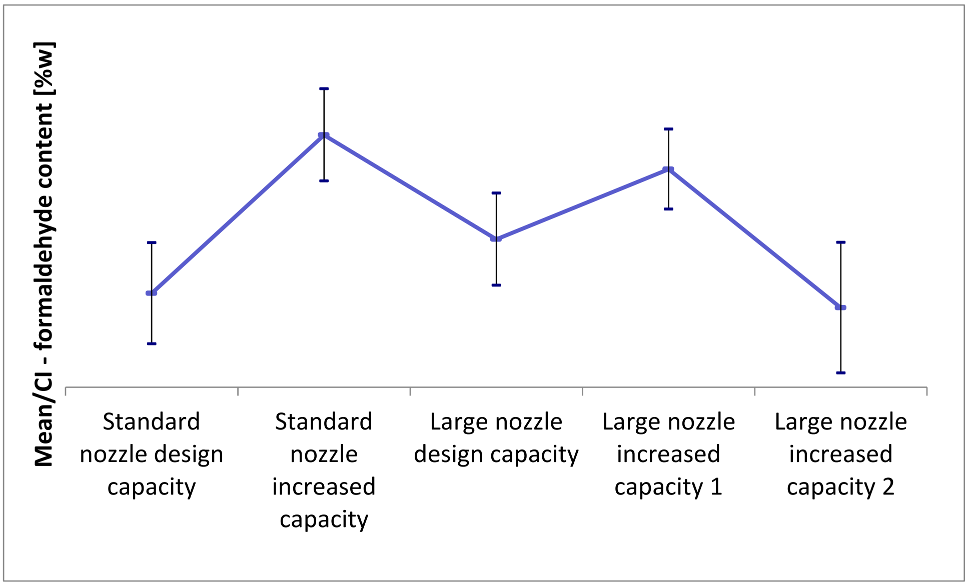


Figure 6: Mean formaldehyde content vs. melt load to two nozzles.

Crushing strength

The mean crushing strength [N] of the standard nozzle was found to be statistically equal to the large-capacity nozzle as depicted in Figure 7.

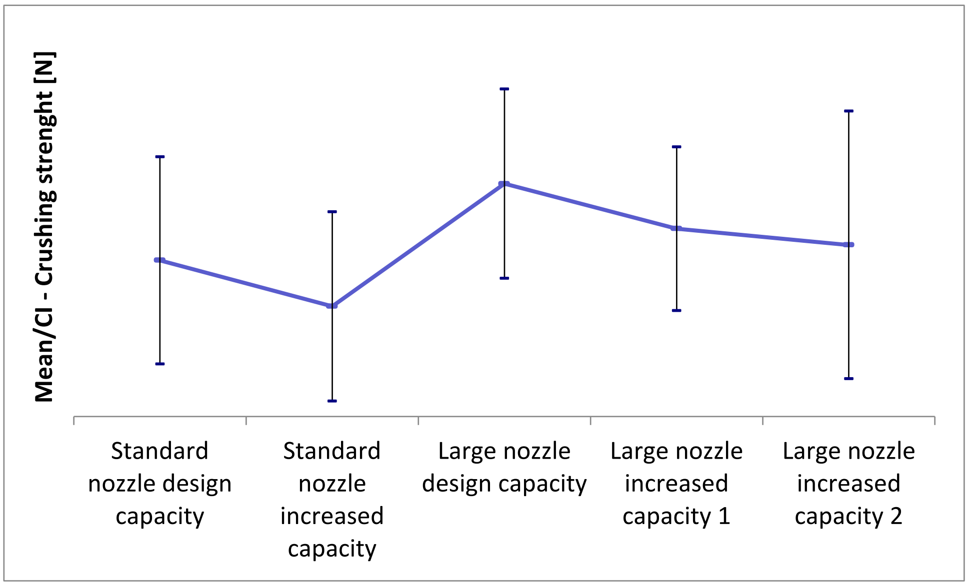


Figure 7: Mean crushing strength vs. melt load to two nozzles.

Caking tendency

The mean caking tendency [bar] of the standard nozzle was found to be statistically equal to the large-capacity nozzle as depicted in Figure 8.

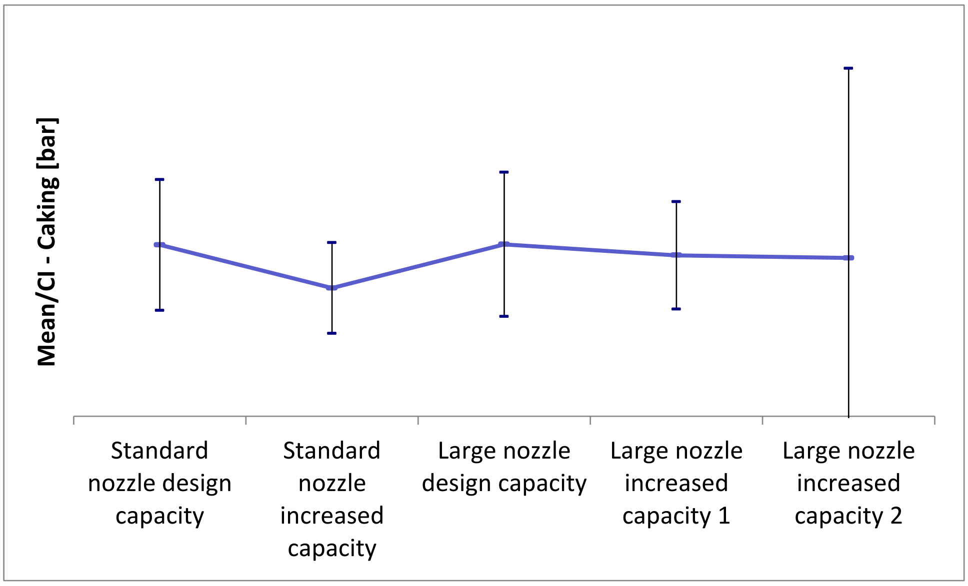


Figure 8: Mean caking tendency vs. melt load to two nozzles.

2.3 Conclusion pilot tests

All tests were concluded with a clean granulator (compartment and walls), clean nozzle and clean air ring after each test run (Figure 9.A) and with production of a fully comparable product between both nozzles (Figure 9.B).

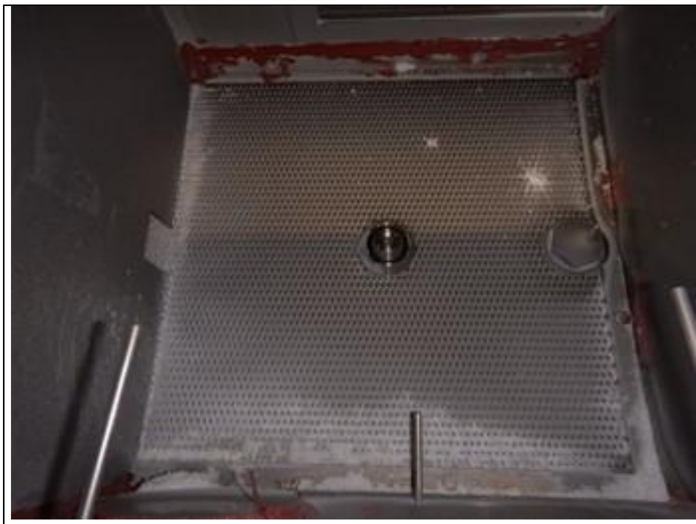


Figure 9.A: Clean granulation compartment, nozzle, and air ring after tests.

Figure 9.B: Urea granules from standard and large-capacity nozzles.

REVAMP DESIGN

3 MELT CONCENTRATION AND REMOVAL OF HEAT OF CRYSTALLIZATION

Maximum performance of the film spraying nozzle is achieved when the water content in the urea melt does not exceed 1.5 wt-%. However, typical feed to the granulator is higher (3–4 wt-%), so while revamping competitors' plants with Stamicarbon's fluidized bed granulation, further concentration is required.

When looking at solutions to achieve the target concentration, a conservative approach is to add another evaporation stage (evaporator, condenser, ejector), as existing systems may not suffice. Some of the competitors' plants already have a second evaporation stage, but they are often only designed to reach 3 wt-%. Bridging the gap to 1.5 %w may require equipment revamp but can be evaluated.

Higher melt concentration means less water, so less heat is removed by vaporization. This increases the heat of crystallization that must be managed in the granulator by other means. To compensate for the reduced cooling effect of vaporization by increasing fluidization air only, the latter should be increased by about 15%. However, simply increasing air velocity is not viable, as it can cause excessive particle entrainment and overload the equipment downstream granulator handling exhausted air.

A solution is often found by applying water injection to fluidization air: instead of increasing air volume, injecting water into fluidization air raises its relative humidity, reducing the need for extra air and helping manage the heat balance more efficiently.

In practice it should be considered that the granulator is designed for worst-case conditions – such as maximum ambient temperature combined with minimum relative humidity – often reached only in extreme cases. For the rest of the year, conditions are less severe from granulation point of view, allowing peaks of higher capacity. With minor modifications, plants can run at higher capacity throughout the year making use of summer-based margins.

4 REVAMPED EQUIPMENT AND OPERATING CONDITIONS

Stamicarbon has successfully performed urea plant revamps for many years, demonstrating expertise and reliability in upgrading existing Stamicarbon and competitor plants. Every revamp is customized to specific client needs and plant conditions, ensuring that the solution is optimal for the client's operational context and technical requirements.

A detailed assessment of the plant is essential. Only after the assessment can the exact configuration and scope of the revamp be determined. This step ensures that all relevant factors (mechanical, process, and operational) are considered.

The configuration described in this paper represents a standard approach when converting a competitor's urea fluidized bed granulation plant to Stamicarbon technology. This configuration has been fully evaluated and is based on Stamicarbon' s extensive experience.

Modifications cover mainly two areas:

- Additional and replaced equipment, and
- Changes in current operational parameters.

Additional and replaced equipment is indicated in red in the PFD below (Figure 11) and is comprised of:

- Additional evaporation stage,
- Water injection, and
- High-capacity film spraying nozzles replacing the atomizing ones.

Regarding other equipment and, in particular, equipment downstream granulator handling air and handling solid, the impact of the revamp is negligible. The reasons for additional evaporation stage and water injection have been extensively explained in previous chapters.

Stamicarbon's high-capacity nozzle has been developed for one-on-one replacement. However, during a feasibility study, considering the variation in systems that competitors have in place, some extra mechanical checks were identified.

The granulator is the primary piece of equipment impacted when assessing current operating conditions and anticipated changes during the revamp. The main changes involve melt, 2ry air – which is also defined as fluidized bed granulation atomization air – and fluidization air. The main changes expected in operation are described below.

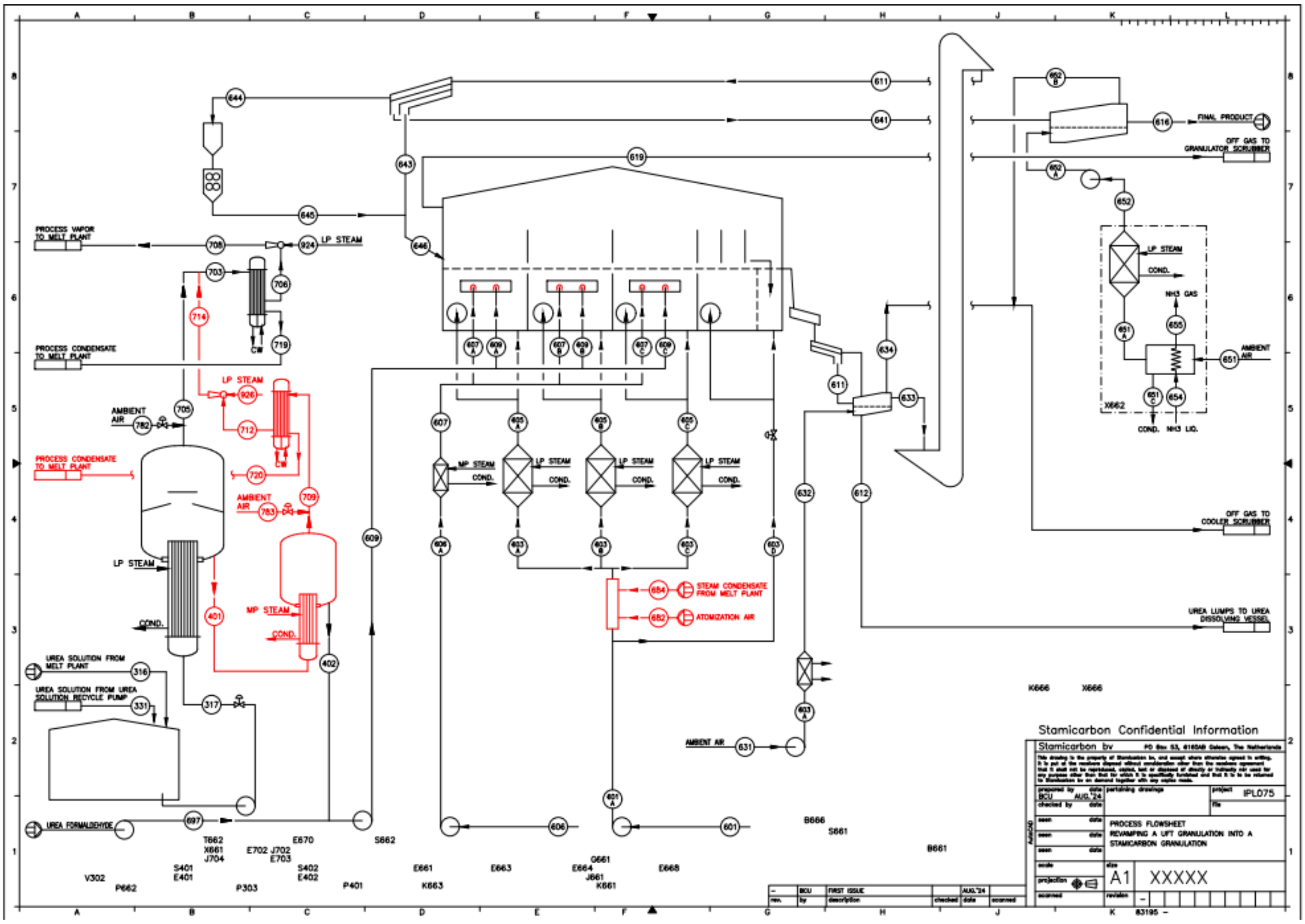


Figure 10: PFD of the revamp design.

4.1 Melt

The new Stamicarbon high-capacity nozzle is engineered to exceed the capacity of competitor nozzles. This design choice keeps the option open for increasing plant capacity during revamp (increased capacity) projects, making it suitable for both direct upgrades and future expansion. However, to achieve the desired spray pattern and granule properties, it is essential that the melt spray nozzle operates near its design conditions. Deviations from these parameters can compromise granulation quality and process stability.

In practice, this could be translated, when upgrading to Stamicarbon fluidized bed granulation without increasing capacity, with isolation of 1-2 headers.

As described earlier in this paper, Stamicarbon's film spraying nozzles are optimized for a melt water concentration of 1.5 wt-%. To achieve such concentration either in existing evaporators or in a new one, optimization between operating pressure and temperature to avoid crystallization and limiting biuret formation is needed.

4.2 Secondary air

The performance of the high-capacity nozzle depends on maintaining a specific mass ratio between the 2ry air and the urea melt. Such ratio is similar for the high-capacity nozzle compared to competitors' systems. However, as mentiioned before, the new nozzles are designed for higher capacity. On the melt side, it is relatively straightforward to isolate or direct flow to specific headers.

Based on Stamicarbon's operational experience, the 2ry air system is typically designed in such a way that the air reaching each header can not be isolated. As a result, when nozzles are upgraded to high capacity, they may not receive enough 2ry air, leading to suboptimal spray and granulation performance. As a result, potential overall slight increase of 2ry air is expected. Such requirement from the exisiting fan can be achieved when looking to the combination of flowrate and pressure.

2ry air is not only necessary for atomization or film formation, but it also prevents crystallization of the urea melt inside the risers (pipes feeding the nozzles). If the air is too cool or insufficient, the hotter melt can crystallize, causing blockages and operational issues. Therefore, Stamicarbon's system requires higher 2ry air temperatures to match the melt temperatures and avoid crystallization. This need could affect the operation of the 2ry/atomization air heaters.

4.3 Fluidization air

The revamp concept will be developed in such a way as to minimize any increase of fluidization air.

Next to the already discussed cooling function of fluidization air, the velocity of air leaving the granulator should be maintained between a minimum and maximum value. Below the minimum value, fluidization is insufficient, leading to poor granule movement and possible process instability while above the maximum value, there is a risk of excessive particle carryover, which can overload downstream equipment like the scrubbing system.

5 CONCLUSIONS

Stamicarbon has developed and successfully tested a patented high-capacity film spraying nozzle to match or exceed the performance of its current standard one, enabling a direct upgrade of competitors' fluidized bed granulators using atomizing spray nozzles. The revamp process involves a thorough plant assessment to tailor the upgrade to the specific requirements of each facility. The typical revamp includes:

- Adding an additional evaporation stage to further concentrate the urea melt,
- Introducing water injection to reduce air temperature, and
- Replacing existing atomizing nozzles with Stamicarbon's high-capacity film spraying nozzles, which are compatible with competitor systems.

The advantages of the Stamicarbon design are focused on the following key areas:

- Reduced formaldehyde consumption.
- Extended run length: Stamicarbon plants can operate continuously for much longer periods (often exceeding 90 days and up to 215 days) before requiring a wash, thanks to lower dust formation achieved by film spraying.
- Limited CAPEX and fast implementation: The revamp solutions are engineered to minimize investment costs and downtime, with typical payback periods of two to three years.

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