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Large Capacity Urea LAUNCH® FINISH™ Granulation Design

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The innovation & license company
of Maire Tecnimont.

Stamicarbon 75 YEARS

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1. ABSTRACT

The first Stamicarbon fluidized bed granulation process and the film spraying nozzle were developed in the late 1970s. This technology was first implemented in a commercial pilot plant in Belarus in 2002 and in a revamp in Canada in 2003. Following these successful revamps, the first grass root plant was started-up in June 2006 in Egypt with a capacity of 2000 MTPD. From that moment on Stamicarbon attended to a request of continuously increasing number of plants with varying capacities.

The next milestone was the start-up of Stamicarbon's first granulation plant with the largest nameplate capacity of 3250 MTPD in 2018. All together Stamicarbon has licensed more than 20 granulation plants until now and experiences with running plants with capacities close to or higher than 3000 MTPD have been positive. Two of these plants, which have different configurations and product requirements, operating under different ambient conditions are easily meeting the performance guarantees.

An investigation has also been carried out for the possibility to scale up the granulation plant up to 5000 MTPD capacity. Assuming a few measures will be implemented in order to avoid/minimize the risks of scaling up the granulator, no real showstoppers for scaling up the granulation plant were found. As a result, Stamicarbon is now ready to build up the first single line 5000 MTPD granulation plant.

2. INTRODUCTION

After the initial development activities conducted in the 1970s, the first commercial test facility was contracted in 1998 at Grodno Azot plant, Belarus, in which a small granulation unit of 280 MTPD was completely converted into a Stamicarbon Granulation Design plant that is part of our LAUNCH® FINISH™ technology series.

After this successful introduction, another scaling up project took place at the Agrium urea complex in Fort Saskatchewan, Canada. Here two existing granulation lines of another licensor of 625 MTPD were converted to the Stamicarbon Granulation Design. The plant commenced granulation production in 2003 and is today still performing very well to the satisfaction of the customer.

The first grass root plant was started-up in June 2006 in Egypt with a capacity of 2000 MTPD. From that moment on, several plants with different capacities all over the world have been put into operation.

The last 10 years saw a rapid increase of projects designed with a considerably increasing maximum capacity of installed plants (See Fig. 1 below).

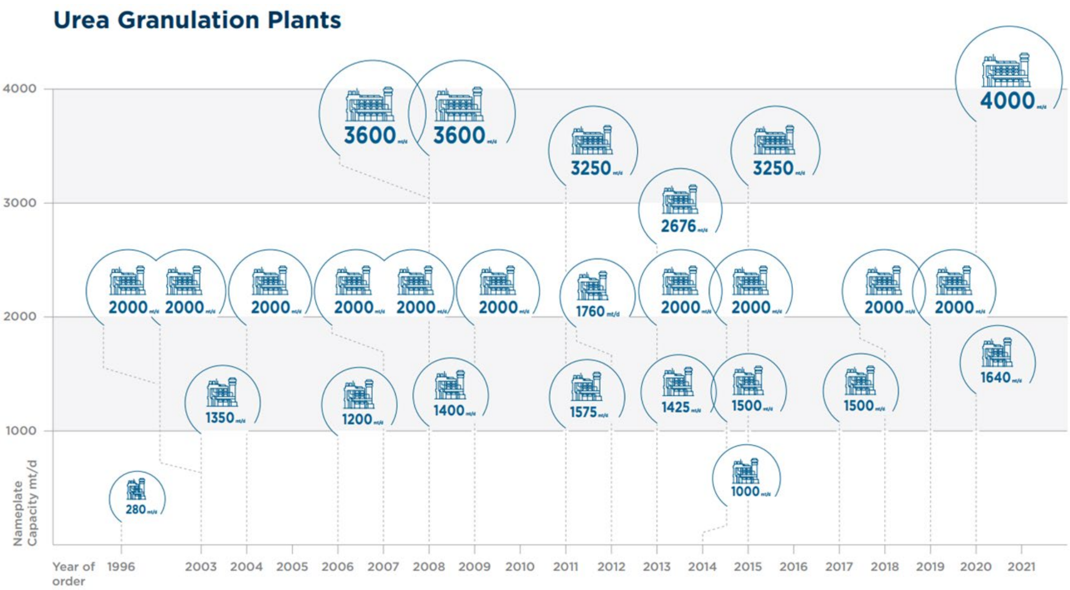

Fig. 1: Stamicarbon granulation licensing timeline

At the moment, the demand growth of urea is about 1.5% per year, equivalent to 3 large scale granulation plants per year. The choice to go for granulated product instead of prilled product is due to the main interest in urea production for export.

Fluidized bed granulation technology offers better strength and handling/shipping capabilities compared to prilling. For that reason, urea granulation plants can be located also in countries at low feedstock cost areas, which allows trouble-free export of the granulated product.

At this moment Stamicarbon urea granulation plants with a capacity close to or higher than 3000 MTPD are in operation. Currently, a single line granulation plant with a capacity of 4000 MTPD is under construction and another commercial project is under conceptual engineering for a single line granulation plant with a capacity of 5000 MTPD.

3. REFERENCE PLANT #1

This reference plant was contracted in 2011 and started up in August 2018. In a short term the plant reached the nameplate capacity of 3250 MTPD.

Fig. 2: Reference plant #1

3.1. DESIGN PARAMETERS

The nameplate capacity of this plant is 3250 MTPD with a capability to operate at 110% capacity and a turn down ratio of 60% of the nameplate capacity. The plant is connected to a LAUNCH® MELT™ Pool Condenser Design plant with the same nameplate plant capacity. This urea plant successfully produces a fertilizer grade urea with the following product specifications.

PRODUCT SPECIFICATIONS		
total nitrogen	wt-%	≥ 46.3
biuret	wt-%	≤ 0.85
water	wt-%	≤ 0.3
formaldehyde	wt-%	≤ 0.3
free ammonia	ppm-wt	≤ 50
temperature	°C	55

Tab. 1: Product specifications for reference plant #1

Expected average granule diameter (d50) is 3 mm. The ambient conditions in the area are quite challenging for the granulation plant design, especially due to the extremely high design ambient temperature of 48˚C.

AMBIENT CONDITIONS		
maximum ambient temperature	°C	52
minimum ambient temperature	°C	5
design ambient temperature	°C	48
ambient pressure	bara	1.013
design relative humidity	%	42

Tab. 2: Ambient conditions for reference plant #1

This granulation plant comprises two fluidized bed coolers: a granulate cooler at the outlet of the granulator and a product cooler for the final product. Regarding the environmental provisions, a two dust scrubber-configuration is chosen: the granulator scrubber taking care of dust scrubbing of exhaust gases coming from the granulator, and the cooler scrubber treating all the remaining air streams i.e. of the fluidized bed coolers. No acid scrubbing for ammonia abatement is installed. The expected emission figures can be seen below:

EMISSION SPECIFICATIONS		
ammonia from granulation stack	mg/Nm^3	≤100
urea from granulation stack	mg/Nm^3	≤ 30

Tab. 3: Emission specifications for reference plant #1

Conventional type of scrubbers are provided by a third party supplier. Urea solution generated in the scrubbing system is recycled back to the urea solution tank in the melt plant.

3.2. PROCESS FLOW DIAGRAM

The granulation design in this plant follows the process flow diagram as illustrated on Fig.3.

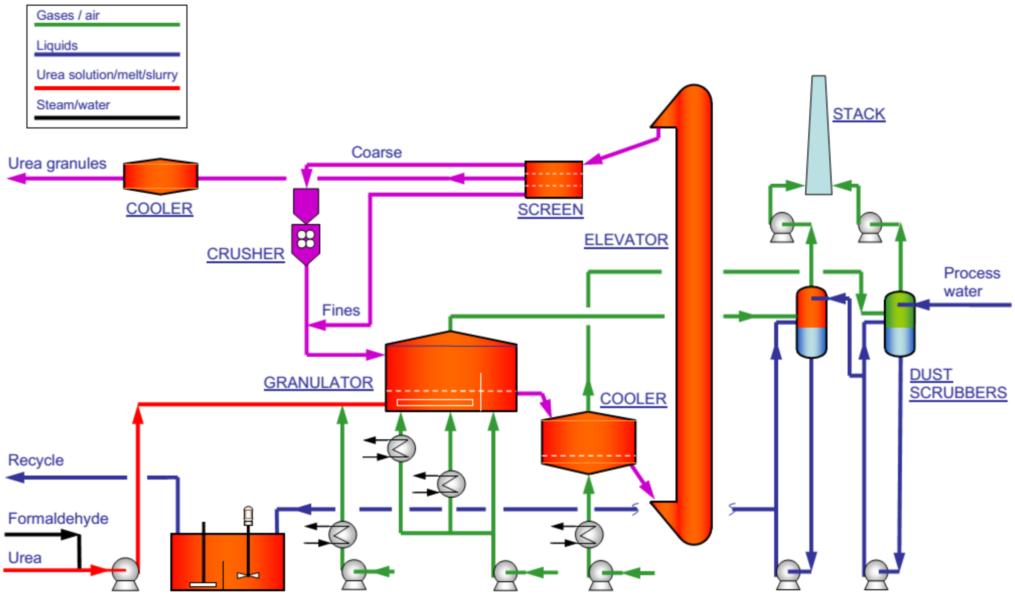

Fig. 3: Process flow diagram of reference plant #1

The process flow diagram reflects the original Stamicarbon granulation process. Urea melt with a concentration of about 98.5 wt% is transferred into the granulator, the core of the process, in which it is distributed in the granulator by a number of film spraying nozzles. As granules move along through the granulation section, their sizes steadily increase by layering and eventually reach the required granule diameter at which the product flows out the granulator.

The air from the granulator, originating from the fluidization and secondary air containing urea dust, is exhausted from the top of granulator by means of the off gas fan in the off gas line of granulator scrubber. The product from the granulator is extracted by an extractor and flows through the lump screen to the granulate cooler.

The fluidization/cooling air, containing some urea dust, is exhausted from the top of granulate cooler and combined with the air from the product cooler and the dedusting air. This combined stream is cleaned in the cooler scrubber system. A bucket elevator lifts the cooled urea granules from the granulate cooler onto the main screens where granule selection occurs.

The on-spec product is cooled down to the desired final temperature in the product cooler. The fine off-spec product is directly recycled to the granulator as seed material. The coarse off-spec product is first crushed and then recycled to the granulator as seed material in the granulator. The scrubbing solutions (diluted urea solution) from the scrubbers are recycled to the melt plant.

3.3. EQUIPMENT PECULIARITIES

3.3.1. Granulator

The granulator was provided by Stamicarbon as proprietary equipment. Pictures of the installed granulator can be seen below.

Fig. 4: Side picture of the installed granulator in the granulation plant

Fig. 5: Front picture of the installed granulator in the granulation plant

3.3.2. Dry recycle loop

Downstream the granulator two parallel product lines are applied. In total two extractors, two lump screens, two bucket elevators, four screens, two diverters, two coarse product bins and two crushers are installed.

Fig. 6: Lump screens installed in the granulation plant

3.4. PERFORMANCE

The plant was running at the time at 90-95% of the nameplate capacity due to limitation on the availability of natural gas.

4. REFERENCE PLANT #2

This reference plant was contracted in 2012 and started up in 2018.

Fig. 7: Reference plant #2

4.1. DESIGN PARAMETERS

The nameplate capacity for this LAUNCH® FINISH™ Granulation Design plant is 2676 MTPD). The turndown capacity is about 50% of the nameplate capacity. The plant is connected to a LAUNCH® MELT™ Pool Reactor Design with a lower nameplate capacity (2200 MTPD). This is due to the fact that a part of the urea solution is imported from another plant in the same area.

The plant is designed to produce granulated urea with traces of sulfur since the salt generated by the ammonia abatement of the acidic scrubbing is recycled back to the granulator. Despite the traces of sulfur, the granules can still be sold as pure urea due to the sufficiently large nitrogen content of the final product.

The plant successfully produces a fertilizer grade urea with the following product specifications.

PRODUCT SPECIFICATIONS		
total nitrogen	wt-%	≥ 46.3
biuret	wt-%	≤ 1.05
water	wt-%	≤ 0.2
formaldehyde	wt-%	≤ 0.3
free ammonia	ppm-wt	≤ 50
sulfur	wt-%	≤ 0.1
temperature	°C	43

Tab. 4: Product specifications for reference plant #2

The expected average diameter (d50) is 3 mm. The ambient conditions for this granulation design are particularly severe during winter, as can be seen below.

AMBIENT CONDITIONS		
maximum ambient temperature	°C	47.8
minimum ambient temperature	°C	-28.9
design ambient temperature	°C	37.8
ambient pressure	bara	0.97
design relative humidity	%	38

Tab. 5: Ambient conditions for reference plant #2

The confirmed emission figures are listed below.

EMISSION FIGURES		
ammonia from granulation stack	mg/Nm^3	≤20
urea from granulation stack	mg/Nm^3	≤5

Tab. 6: Emission figures for reference plant #2

Urea ammonium sulfate solution formed in the acid scrubbing system is processed within the battery limit of the granulation plant using a dedicated evaporation section. The concentrated solution is then recycled back to the granulator.

4.2. PROCESS FLOW DIAGRAM

The process flow diagram below depicts the LAUNCH® FINISH™ Granulation Design for reference plant #2.

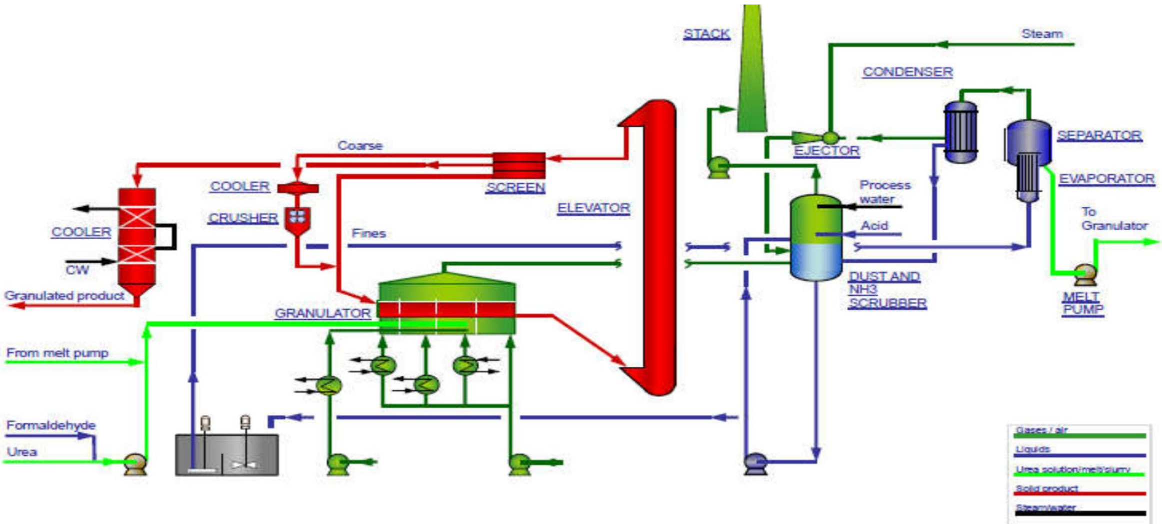

Fig 8.: Process flow diagram of reference plant #2

The granulation plant design was further optimized for reference plant #2 when compared to the process flow diagram of reference plant #1. Here Stamicarbon introduced a much simpler concept, in order to save on both investment and operating costs, with the following main changes.

- The fluidized bed granulate cooler was omitted by increasing the length of the cooling zone of the granulator, thus integrating the function of the fluidized bed granulator cooler inside the granulator. A smaller fluidized bed cooler was implemented upstream the crusher only for cooling down the coarse product.

- The fluidized bed product cooler was replaced by a solids flow cooler.

- Due to omitting the two large sized fluidized bed coolers, the respective granulator cooler scrubber, with all necessary pumps and fan, could also be omitted.

In this configuration the granules are cooled down further in the fourth compartment of the granulator, therefore only a crusher feed cooler for cooling down the coarse product is foreseen as a separate fluidized bed cooler. Dust-laden air stream exiting the coarse product cooler can also be handled in the single scrubber system. The final product is cooled down with cooling water in a solids flow cooler before being sent to the battery limit.

Furthermore, because of a unique request at the time by the client, the MicroMist™ Venturi (MMV) Scrubber with acidic scrubbing was placed. Generated ammonium sulfate is recycled back to the granulator after a dedicated evaporation step is performed.

4.3. EQUIPMENT PECULIARITIES

4.3.1. Granulator

The granulator was provided by Stamicarbon as proprietary equipment.

4.3.2. Dry recycle loop

Like for reference plant #1, two parallel product lines are applied downstream the granulator.

4.4. PERFORMANCE

The plant is currently running successfully up to 107% of the nameplate capacity.

5. LESSONS LEARNED

According to Stamicarbon's experiences with designing granulation plants with large capacities, certain technological challenges upon scaling up the Granulation Design have been identified together with possible supporting measures.

These challenges can be identified in two categories: operational and manufactural. While the operational challenges have been tackled by Stamicarbon's engineering team members, who have extensive knowledge in granulation operation, solutions for the manufactural challenges have been comprehensively investigated together with Stamicarbon's preferred vendors.

The points of attention were mainly focused on the following sections.

- Granulator
- Dry recycle
- Other solid handling equipment

5.1. CRITICAL POINTS FOR THE GRANULATOR

Stamicarbon's current approach is to fabricate and deliver the proprietary granulator as one piece of equipment due to several advantages such as ease of transportation and installation, minimizing potential damage to the equipment, lower packaging costs, etc.

The final design of the granulator in terms of sizing and area is mainly influenced by various parameters such as capacity, maximum ambient temperature, relative humidity at maximum ambient temperature and design pressure.

Following critical points for the granulator have been investigated during designing large capacity plants.

1) Changes in particle size distribution (PSD) of the granules

Due to the width (W) limitation of the granulator at the vendor workshop, at some point scaling up the granulator results in increasing the length (L) of the granulator only. As a consequence an L/W ratio beyond standard values can be reached for large capacity plants. From mechanical perspective, an alternative to increasing L/W is to manufacture and transport the granulator in two pieces. However, having the granulator fabricated and shipped in one piece in horizontal direction (comprising already assembled headers) has certain advantages:

- The possibility of damage during transportation and installation is minimized.
- No additional cost for the packaging of the headers (would need to be supported in a ridged frame).
- Depending on the manufacturer challenges with respect to installation sequence which could increase the (pre-)commissioning activities are avoided.
- Risks regarding the responsibilities of the on-site installation activities and availability of manpower (Stamicarbon and manufacturer) are limited.
- By installing the headers in-shop, any issues with respect to the installation of the headers can be fixed in a controlled environment.

A larger L/W ratio influences the residence time in the granulator. The flow pattern in the granulator will rather approach plug flow than a continuous stirred tank, which might affect the particle size distribution. In order to keep the flexibility to deal with the variability in the particle size distribution, the measures have been taken in terms of both flexible design (“dry recycle” ratio) and configuration of solid handling equipment (e.g. main screen mesh size).

2) Higher biuret formation

Since length of the granulator will increase, the length of the melt header will also increase, leading to a larger residence time and hence the biuret formation. In order to minimize such an increase in biuret formation and, at the same time, limit the pressure drop, Stamicarbon has developed a new proprietary melt header system design.

3) Maldistribution of granules over the fluidization plates

Due to the absolute larger granulator width and the larger L/W ratio, a bigger part of the granules can follow a straight path through the compartment without being properly sprayed over by melt. This will have an influence on the shape and particle size distribution leaving the granulator. For the same reason, some granules can also follow a straight path through the cooling compartment without being cooled properly. In order to allow proper distribution across the width, orientation of dry recycle inlet lines and baffles has been redesigned.

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4) Increased granulator off-gas load

Due to the increased capacity, the absolute amount of off-gas leaving the granulator will increase. Stamicarbon's preferred vendors for off-gas scrubbing systems confirmed that such large off-gas flows can still be treated in a single scrubbing unit. However, this increase in outlet air flowrate has consequences both for the granulator height and the overall plant layout. In order to minimize the increase in height, shape of the off-gas nozzle and duct has been optimized.

5) Monitoring and controlling the granulator operation

Due to the larger sized compartments of the granulator, proper monitoring and controlling the granulation operation can be challenging. Selection and installation of the right instrument at the right location becomes crucial in overcoming this challenge. In that regard, Stamicarbon has developed a new process control system that can be implemented in large scale granulators for precise monitoring and controlling of the granulator operation.

6) Impairing the structure of the granulator

A mechanical analysis has been performed to check the mechanical integrity of large scale granulators. This resulted in the necessity of implementing extra supporting stiffeners in order to prevent potential mechanical damage to the granulator. It is known that severe fouling could potentially occur around stiffeners inside the granulator. Stamicarbon has also taken extra measures in the design of the stiffeners in order to minimize the fouling.

5.2. CRITICAL POINTS FOR DRY RECYCLE

Besides the granulator, the critical pieces of equipment that may become bottlenecks for reaching the name plate capacity are the main screens and the crusher.

For a 5000 MTPD Granulation Design, the dry recycle flow can be considerably high. The total amount of this recycle flow shall be handled by the main screens and about one-fourth of this flow is sent to the crusher. In consultation with our preferred vendors for these two pieces of equipment, we defined the maximum capacity each equipment can handle and, in this way, optimized both the number of equipment and the plant layout.

The conclusion is that for a 5000 MTPD Granulation Design at least four main screens and three crushers are needed. The required number of main screens in relation to the required number of crushers is not in line with the current Stamicarbon design, in which each bucket elevator is followed by two screens, one coarse product cooler and one crusher. Therefore, the main bottleneck was found to be the crusher due to its maximum capacity.

Even though based on the capacity three crushers is sufficient for this plant, considering more uniform distribution of product into the crushers, the number of crushers is selected to be with the same as the number of main screens. In this way, it is also possible to couple four crushers with two coarse product coolers and eventually a further decrease in plant height is achieved. Moreover, based on the investigation carried out by one contractor, it is also confirmed that the overall plant cost (incl. civil costs) is lower if a symmetrical lay-out is applied, meaning that a four crusher set-up is more beneficial than a three crushers setup in terms of CAPEX.

5.3. CRITICAL POINTS FOR OTHER SOLID HANDLING EQUIPMENT

The remaining process equipment is not as critical in terms of capacity. Based on the expertise of our preferred vendor for the solid flow type final cooler, a single unit can be applied for large capacities as large as 5000 MTPD. The possibility to have two units in parallel, especially in order to guarantee a certain flexibility in operation, can be considered as well.

6. SCALING UP TO HIGHER CAPACITIES

6.1. WHY SINGLE LINE INSTEAD OF TWO LINES

Choosing either a single line with large capacity or two lines for smaller capacities operating in parallel was also investigated taking the following two options into consideration.

A) Single line of 5000 MTPD capacity
B) Two lines of 2500 MTPD capacity each

It was concluded that from a design point of view, three points required special attention.

1) Using 6 main screens for option A, instead of 2 x 2 main screens for the option B, may lead to an extra challenge with respect to the layout for placing these 6 screens and distributing the product exiting 2 elevators properly over these 6 screens.
2) Using 3 crushers for option A, instead of 2 x 2 crushers for the option B, may create some operational issues with the maximum capacity that can be handled by a single crusher.
3) Using two product coolers in parallel for option A, instead of one for the option B, can overcome the problem of the height of the cooler as the limiting factor.

Regarding option B, it was assumed that no synergistic advantages were obtained in the building of two identical copies of a plant at the same time except for organizational, such as engineering. A possible synergy in terms of engineering, process design, purchase, etc. can still be expected, although being limited.

With regard to option A, it brings less operational flexibility in terms of plant turn down ratio. In case of both foreseen (e.g. granulator washes) and unforeseen (e.g. an upset condition in the melt plant) situations, the full production capacity will be lost in option A, whereas in option B one of the two lines could keep on running.

The main conclusion of the study regarding the investment cost was that a CAPEX saving of up to 30% (on total investments) appears attainable in option A compared to option B.

6.2. LEARNINGS FROM THE DESIGN OF 4000 MTPD PLANT

Since late 2019 Stamicarbon has been involved in establishing a single-line 4000 MTPD granulation plant as the licensor, for which the design phase has been completed and the construction phase is currently on-going. Throughout the design and equipment supply phases of this project, Stamicarbon had the opportunity to put the above mentioned lessons learned into practice due to the large capacity of this plant. Some of the key learnings from this large capacity project are listed below.

- Plant layout and height relations: Due to the bigger sizes of the equipment, the plant layout becomes quite critical in terms of both equipment and piping. Special attention is needed to be paid for the plant layout in order to:

    - Minimize the overall granulation plant height and the footprint without compromising the overall performance
    - Satisfy the design criteria for critical process lines such as melt line, dry recycle lines, final product line, etc.
    - Place solid handling process equipment in the most optimum orientation in order to minimize product breakage

- Melt header orientation: In a granulation plant, melt header travels along the length of the granulator before reaching the first header in the first compartment. For that reason, the length of the granulator, which is proportional to the capacity of the plant, plays an important role in the orientation of this melt header in terms of residence time, and thus biuret formation. In addition to this, the melt header should be designed in a way to prevent stagnant flow and consequent crystallization of the melt.

- Granulator air outlet duct: Due to the large amount of dust-laden air leaving the granulator, the duct size may become critically large and this may result in a system which is prone to blockage due to dust accumulation if not sufficient slope and dust washing provisions are made available. The orientation of this large ducting may also become critical due to the limited available space between the granulator building and the off-gas scrubber.

- Off-gas scrubbing system: For the same reason of the large amount of dust-laden off-gas air, the off-gas scrubber will eventually have a very large diameter. Therefore, it is crucial to ensure uniform distribution of this air flow across the scrubber cross-section for the most optimum removal of dust and, in case of the presence of acidic scrubbing, ammonia. In addition to this, due to the large and heavy structure of such an off-gas system, extra precautions from a mechanical perspective such as foundation, supporting, locations of pumps and piping, etc. should be taken early in the project.

7. CONCLUSIONS

Recent experiences with two running Granulation Design plants with capacities around 3000 MTPD have been very positive. Both plants, which have different product requirements and configurations, and which operate under different ambient conditions, have easily met the performance guarantees. Moreover, from investigation on the possibility to scale up the Granulation Design to a single line 5000 MTPD plant, it was concluded that there are no showstoppers for such a large capacity, provided that certain additional measures are implemented to anticipate on the risks of scaling up. Furthermore, a single line of 5000 MTPD is estimated to have a 30% less CAPEX as compared to two lines of 2500 MTPD each. Stamicarbon is therefore now ready to build the first single line 5000 MTPD Granulation Design. At the moment of writing this paper, design of a 5000 MTPD granulation plant has been completed and a 4000 MTPD plant is under the engineering phase.

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