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Experiences with MicroMist™ and Jet Venturi scrubbing systems

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Stamicarbon 75 YEARS

EXPERIENCES WITH MICROMIST™ AND JET VENTURI SCRUBBING SYSTEMS

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1. ABSTRACT

Worldwide, fine particulate emission regulations are becoming increasingly strict. In response to this, Stamicarbon and EnviroCare International have co-developed the MicroMist™ Venturi Scrubber for granulators and the Jet Venturi Scrubber for prilling towers. Compared to conventional scrubbing solutions, these innovative, high-performance scrubbers remove not only coarse urea particles, but also submicron urea dust and ammonia gas at extremely high efficiencies.

Based on the initial real-plant experiences with MicroMist™ Venturi Scrubbers and on-site tests conducted with the Jet Venturi Scrubber, it is possible to conclude that Stamicarbon's emission technologies can allow plant owners to exceed the requirements of the most stringent environmental regulations, ensuring sustainable plant operation in the coming decades.

Apart from the grass root plants, these scrubbing technologies can also be used for revamping existing granulation scrubbers (EVOLVE EMISSION™ MicroMist™ Venturi Scrubber) and prilling plants (EVOLVE EMISSION™ Jet Venturi Scrubber) to the latest environmental standards for urea dust and ammonia.

This paper analyzes the operational aspects of the first on-stream MicroMist™ Venturi Scrubbers. The modifications and improvements applied during start-up compared to the original design are evaluated. Possible future improvements in relation to the layout and internals of the scrubbing system are also explored. Moreover, conducted pilot tests and conceptual design development for the Jet Venturi Scrubber are disclosed.

2. INTRODUCTION

Urea prills and granules are produced from highly concentrated urea melt solutions. When the melt is sprayed into a prilling tower or a granulator, the air is used to crystalize and cool it down to the required temperature. The off-gas must be cleaned before being released into the atmosphere because it contains urea dust and ammonia. To reduce dust emission, typically, wet scrubbing is applied by bringing dust-laden air in contact with the circulating aqueous solution.

In both granulation and prilling, substantial submicron dust is generated. While conventional scrubbing technologies easily collect larger particles, a high degree of submicron dust capture requires a new approach. Stamicarbon and EnviroCare International have partnered to develop scrubber technology capable of achieving extremely high efficiency in collecting submicron dust particles and fulfilling the most stringent dust emission requirements.

Additionally, during the crystallization process of the urea melt in a granulator or a prilling tower, the ammonia present in the urea melt is released and emitted into the air. Despite high ammonia solubility in water, water washing proves to be ineffective in removing ammonia from the dilute, low-pressure off-gases from the granulation or prilling plant. In addition, gas/liquid contact time is insufficient for the significant transfer of ammonia from gas to liquid.

To efficiently capture ammonia, the application of acidic scrubbing is required. Sulfuric or nitric acid is injected into a circulating aqueous solution brought into contact with the ammonia-laden air. Applied acid reacts with ammonia, effectively reducing its concentration in the exhaust air. An ammonium salt generated in this reaction can be sent OSBL or incorporated into the urea end product.

3. MICROMIST™ VENTURI SCRUBBER

3.1. FIRST REFERENCE PROJECT: OPERATIONAL EXPERIENCE AND COMPARISON TO THE ORIGINAL DESIGN

The first MicroMist™ Venturi (MMV) Scrubber is installed in a large-scale single-line Stamicarbon urea granulation plant. An acidic scrubbing stage is included for reducing ammonia emissions. The Wet Electrostatic Precipitator (WESP) is also part of the design package; per the client's request, the dust emission has to be reduced below 5 mg/Nm^3.

The ammonium sulfate generated in a reaction between the ammonia present in the off-gas and the injected sulfuric acid is recycled back into the granulator together with the collected urea dust as a urea ammonium sulfate (UAS) solution. In this way, no disposal streams are sent to battery limits. The UAS solution contains about 55 wt-% water and cannot be directly mixed with the main urea melt feed that contains merely 1.5 wt-% water. To reduce the water content of the UAS solution recycled to the granulator, a dedicated evaporation step is applied (see Fig. 1).

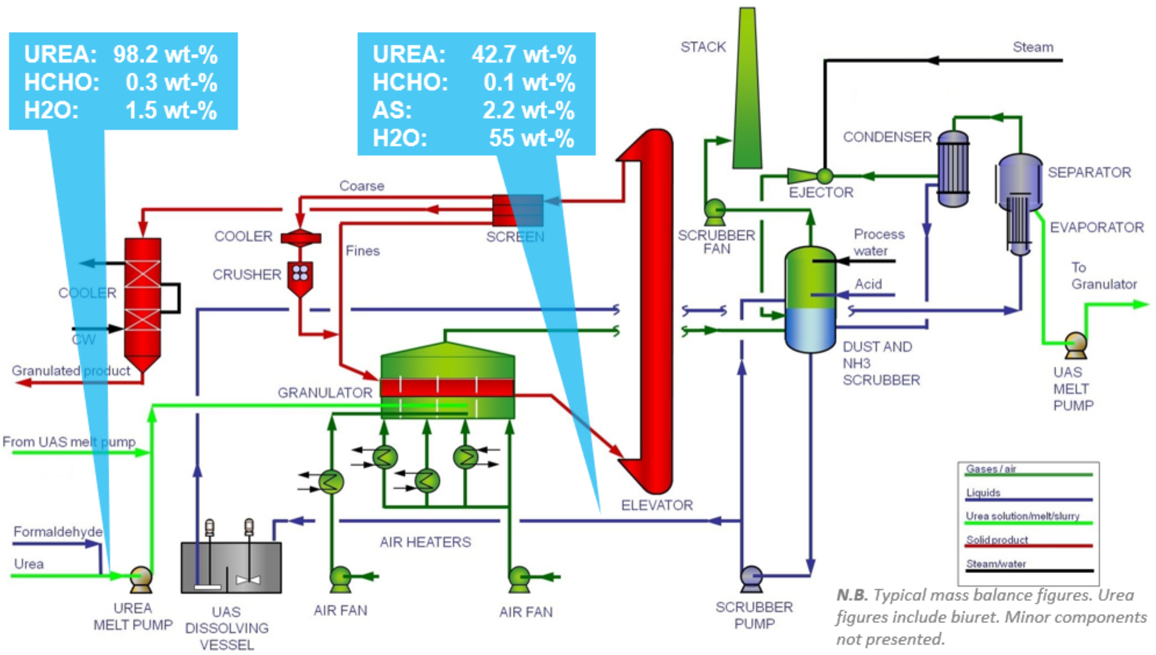

Fig. 1. Process flow diagram of an urea granulation plant

The concentrated UAS solution is shaped together with urea melt in the granulator. The resulting sulfur content of about 0.05-0.1 wt-% in the final product is almost negligible, meaning that the granulate is still sold as standard urea.

The following design and operational aspects of the first MicroMist™ Venturi Scrubber are analyzed further in the text:

- Original design of the MicroMist™ Venturi Scrubber
- Initial performance of the MicroMist™ Venturi Scrubber and operational deviations
- Mitigation strategy: operational and temporary solutions
- Urea dust emissions and opacity
- Experience with the second reference unit
- MicroMist™ Venturi Scrubber design improvements

3.1.1. Original design of the MicroMist™ Venturi Scrubber

The original scrubber design in the first reference plant is presented in Fig. 2. Exhaust air coming from the granulator enters the first vessel, the quench stage. Circulating UAS solution is sprayed into the airflow. The airflow has a temperature of about 100 °C while the UAS solution is at 40 °C. Because of the difference in temperature, the water present in the gas flow condenses on top of the dust particles promoting the urea dust collection process. The largest dust particles are separated from the airflow in the quench vessel. Lean urea solution coming from the sump of the MicroMist™ Venturi vessel is used as a make-up for compensating water losses due to evaporation in the quench stage.

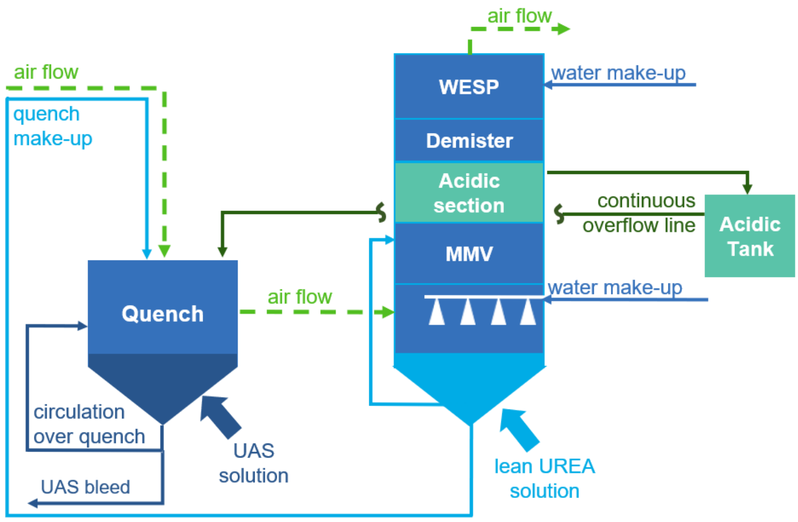

Fig. 2. MicroMist™ Venturi Scrubber design in the first reference plant

The cooled and partly saturated air leaves the quench vessel and, via the cross-over duct, enters the bottom section of the MicroMist™ Venturi Scrubber, where the conditioning and saturation process continues by spraying process condensate as a mist of droplets into the airflow. The process condensate acts as the main make-up water source in the scrubbing system. Then, the airflow enters the MicroMist™ Venturi stage consisting of several venturi elements installed in parallel, where lean urea solution from the sump of the MicroMist™ Venturi vessel is sprayed as a fine mist into the airflow. The urea solution mist collides with the submicron dust particles on the way in and out of the MicroMist™ Venturi elements and separates them from the airflow.

After leaving the MicroMist™ Venturis, the air is introduced into the acidic scrubbing part, where the ammonia content of the air is reduced using a sulfuric acid solution circulated over the acidic scrubber trays. The ammonia reacts with sulfuric acid to form ammonium sulfate. The ammonium sulfate solution from the trays discharges into the acidic tank, which continuously overflows to the quench vessel. The airflow leaving the acidic part passes a mist eliminator (demister) to prevent entrainment of acidic mist to the downstream equipment. Next, the airflow enters the WESP, where cooled steam condensate is supplied to wash its walls, also serving as a second (minor) source of make-up water to the scrubbing system. The cleaned air is collected by the scrubber fan and via a stack exerted to the atmosphere.

A few overflow lines are incorporated for preventing overfilling scenarios:
- From the MicroMist™ Venturi vessel into the quench vessel,
- From the quench vessel into the dissolving tank of the granulation plant.

3.1.2. Initial operational deviations in operating MicroMist™ Venturi Scrubber

The MicroMist™ Venturi Scrubber was successfully started up without major issues and with satisfactory initially achieved scrubbing efficiency. This was a significant milestone in the overall development process of the MicroMist™ Venturi Scrubber. However, also some deviations compared to design operation were identified:
- There was no lean urea solution in the MicroMist™ Venturi sump but rather a solution with substantial urea content,
- There was no sufficient lean urea solution available to compensate for the evaporation losses in the quench vessel (see Fig. 3 below).

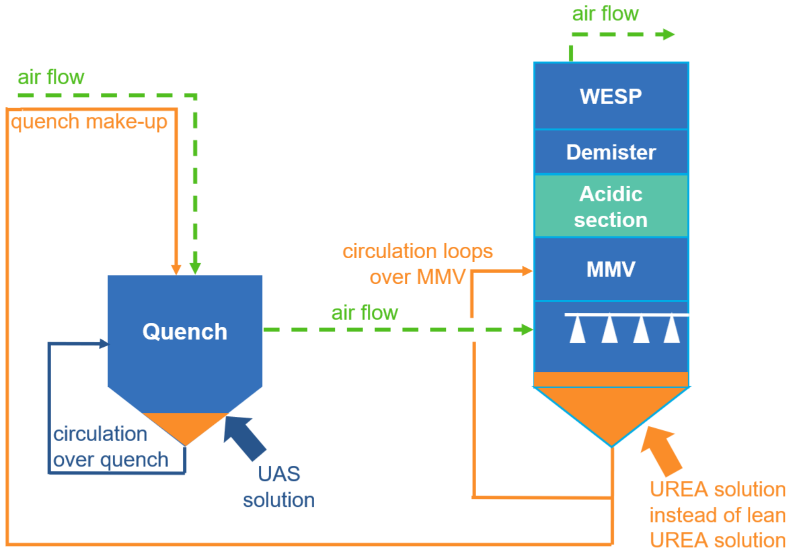

Fig. 3. Solution with significant urea content identified in the MMV sump

Operational solution for overcoming issues related to initial deviations

To be able to operate the scrubbing system, the level in the MicroMist™ Venturi vessel was increased to the maximum level possible, eventually using the overflow line for supplying make-up liquid to the quench vessel (see Fig. 4 below):

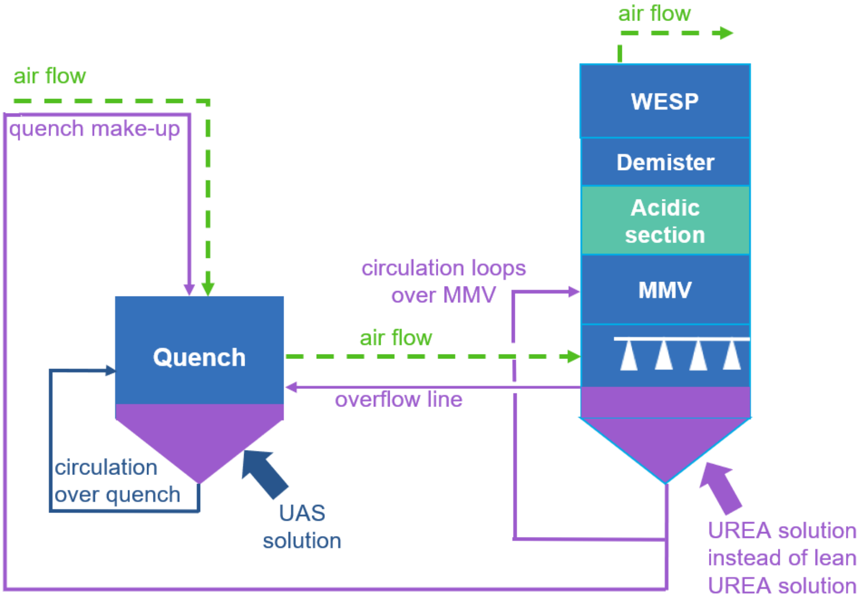

Fig. 4. Overflow line used as a continuous make-up supply line for the quench stage

Root cause of the initial deviations

The airflow from the quench vessel to the MicroMist™ Venturi vessel carried away a large amount of liquid, which was not foreseen in the original design (see Fig. 5 below). The liquid in the quench vessel was rich in urea, resulting in a concentrated urea solution present in the sump of the MicroMist™ Venturi vessel.

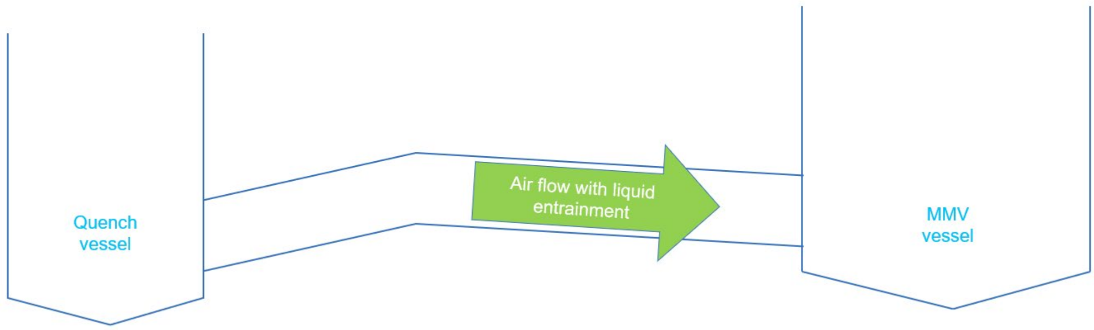

Fig. 5. Urea-rich liquid entrainment from the quench vessel to the MMV vessel sump

In order to properly operate the scrubbing system, decreasing the urea concentration in the MMV vessel sump was required. An easy, fast and relatively cheap solution was to install a trench in the cross-over duct to act as a drain catch, as indicated in Fig. 6.

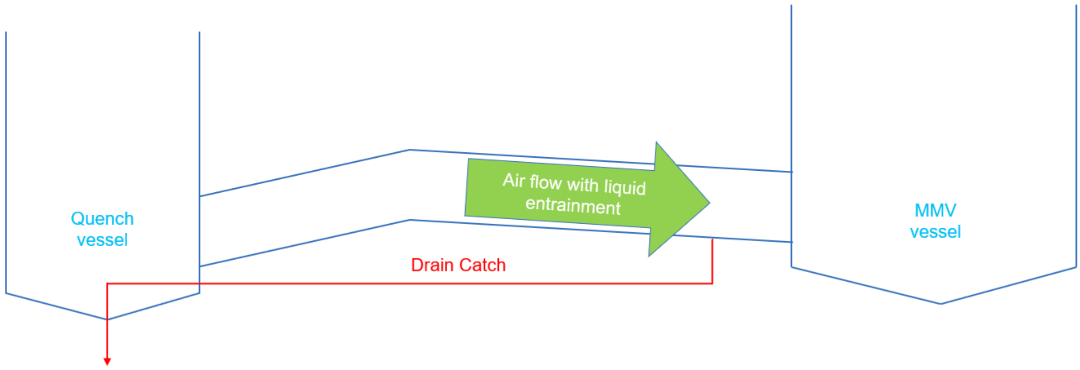

Fig. 6. Drain catch for keeping entrainment in the quench stage

By using the trench solution, it was possible to decrease the urea concentration in the MicroMist™ Venturi sump to an acceptable operational level. At the same time, the liquid entrainment was returned by gravity back to the quench vessel, avoiding the upset of the quench stage water balance.

3.1.3. Additional operational deviations

A further consequence of the initial deviations was urea entrainment going from the MicroMist™ Venturi section into the acidic section, as indicated in Fig. 7.

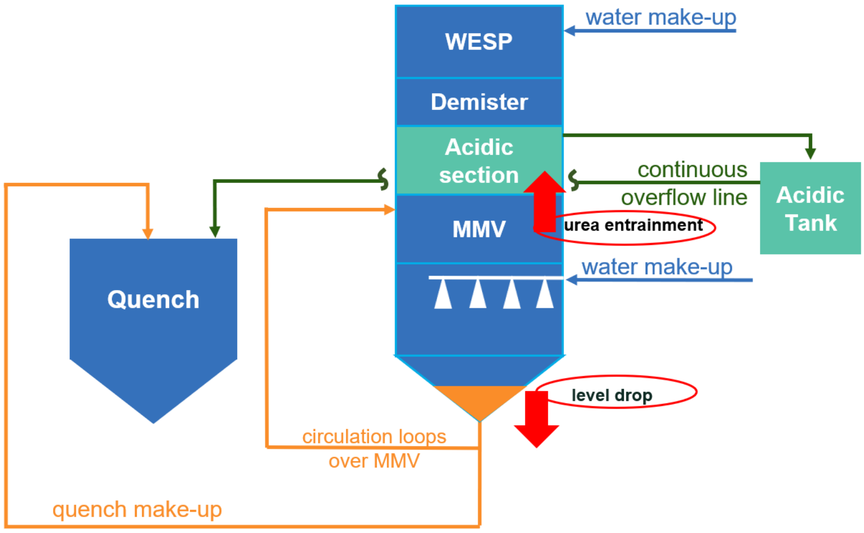

Fig. 7. Urea entrainment to the acidic section and level loss in the MMV vessel sump

Moreover, as a result of having more concentrated urea solution in the sump of the MicroMist™ Venturi Scrubber, when putting into operation one of the pumps used to circulate this urea solution over the Venturi stage, the level in the MicroMist™ Venturi sump was decreasing faster than it could be maintained with the water make-up. To avoid cavitation, it was necessary to stop the recirculation pumps.

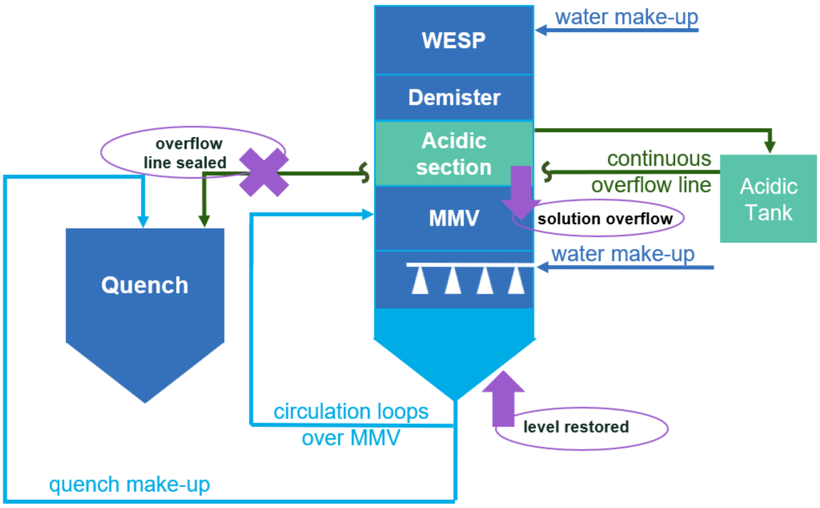

Fig. 9. Level restoration in the MMV vessel sump

Operational solution for overcoming issues related to the additional deviations
In order to solve this issue, it was decided to seal the overflow line going from the acidic tank into the quench vessel. In this way, the water entrained from the MMV stage to the acidic section was falling back into the MicroMist™ Venturi sump, effectively restoring the level in the sump.

3.1.4. Realized scrubbing efficiency

Despite these operational difficulties experienced during commissioning, the measured urea dust emissions were within the expected level from the early start-up. Dust emissions recorded during official testing were less than half the stringent target of 5 mg/Nm^3 while having 0% opacity. The results represent a major milestone for urea producers, as they confirm that Stamicarbon's urea granulation plants can go beyond the most stringent global urea dust emission requirements.

3.2. SECOND REFERENCE PROJECT: OPERATIONAL EXPERIENCE AND COMPARISON WITH THE FIRST REFERENCE PROJECT

The experience of the first project was intertwined with a second project. Both projects with the MicroMist™ Venturi Scrubber went into operation in 2018. Both plants are the first Stamicarbon plants to incorporate this new scrubbing technology engineered by Stamicarbon's partner EnviroCare International. One key difference in the design of the two MicroMist™ Venturi Scrubbers is the addition of a separation stage between the MicroMist™ Venturi section and the acidic section for the second project. Unlike in the first project, the resulting ammonium sulfate (AS) solution from the acidic scrubber is not reworked in the granulator but further processed outside battery limits (see Fig. 10). Due to the requirement to have low urea concentration in the obtained AS solution, an additional mist eliminator is installed between the MicroMist™ Venturi section and the acidic section.

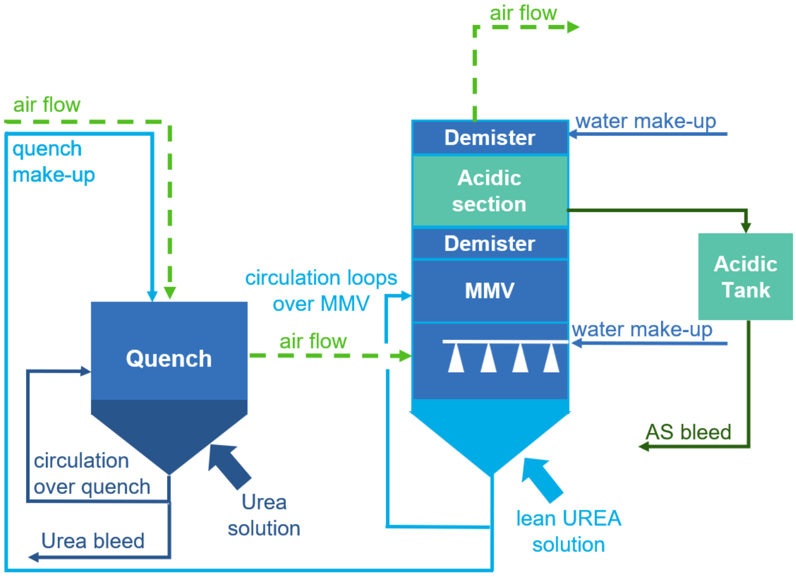

Fig. 10. MicroMist™ Venturi Scrubber design of the second reference project

Similar to the first project, there was liquid entrainment from the quench vessel into the MicroMist™ Venturi vessel during the initial start-up, resulting in increased urea concentration in the lean urea solution. On the other hand, the urea entrainment to the acidic section, as identified in the first reference plant, was not present due to the additional separation stage between the MicroMist™ Venturi Scrubber section and the acidic section. The demister worked well, and this stage is to be incorporated into the design for all future applications, where needed.

Meanwhile, the official measurements reported 0% opacity (EPA Method 9) and particulate emissions lower than the expected amount of 10 mg/Nm^3, measuring both filterable (EPA Method 5) and condensable (EPA Method 202) particulate matter. This is an outstanding achievement since these numbers were realized with the initial start-up scrubber settings without any optimization or fine-tuning of the scrubber operation.

3.3. NEW MICROMIST™ VENTURI SCRUBBER DESIGN

In relation to the lessons learned at both operating references, an updated design has been introduced for future projects. The main upgrades applied are:

- Optimization of the quench sump to optimize the water balance with a reduced CAPEX design.
- MicroMist™ Venturi wastewater management is optimized to provide increased reliability in recycling water streams for the various applications within the scrubber.
- In the case of using nitric acid as an acidic medium, the scrubbing unit can be converted into a small urea ammonium nitrate (UAN) production unit. Such adjustment would allow to avoid having any waste product and convert the acid into UAN directly in the scrubber. In this way,

two operational issues are solved with one solution, as the acid is used to reduce ammonia emissions while upgrading the waste salt as a finished final product.

- To enable training of operators on using the MicroMist™ Venturi scrubber, Stamicarbon has incorporated the scrubber package within its dedicated high-fidelity Operator Training Simulator of the granulation plant. The simulator allows operators to run the scrubber in different operational modes and trains them on reaching the optimal performance of the scrubber.

JET VENTURI SCRUBBER

Despite its very low vapor pressure, some of the urea evaporates after being sprayed by the bucket into the prilling tower. Subsequent cooling and deposition of this gaseous urea results in the formation of submicron dust particles. Consequently, the exhaust gas from a prilling tower has very fine dust, with an extremely large surface area and the share of submicron particles reaching up to 70 wt-% of the total dust load. Such fine dust creates a highly visible, persistent purple-white plume that neither mixes well with the surrounding air nor dissipates easily. As a result, environmental regulations for prilling tower emissions are becoming stricter. Allowed emission levels are currently a maximum of 50 mg/Nm³ for dust and 50 mg/Nm³ for ammonia in Europe. The limits are even more stringent in some other regions. In that regard, Stamicarbon and EnviroCare International have been working on developing Jet Venturi Scrubber, scrubbing technology for prilling towers capable of reaching very low emission levels.

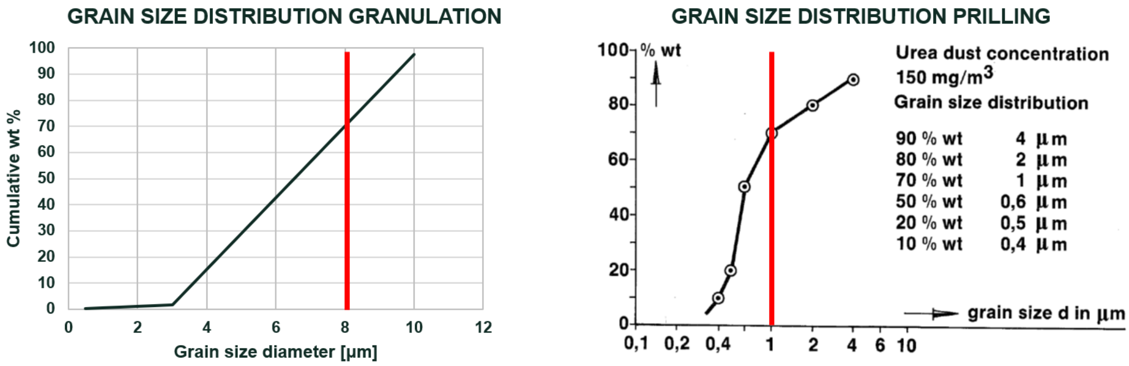

Fig. 11. Typical particle size distribution for dust in the off-gas of granulation and prilling plants (indicating the particle size for 70 wt-% cut)

The already developed MicroMist™ Venturi scrubbing technology for granulation plants was the starting point. The idea was to utilize the same principle but adapt it further in line with the specifics of the prilling tower off-gas, the most significant being the high content of submicron particles (Fig. 11).

4.1. JET VENTURY SCRUBBER DESIGN

The technology is suitable for both natural and forced draft prilling towers. The scrubbing unit can be placed at grade level or on top of the prilling tower. The latter is preferable since less ducting is required. Besides CAPEX-related benefits, this also means no additional pressure drop to the overall system. Moreover, by utilizing the jet effect of the applied Venturis, the dust scrubber moves the off-gas itself without the aid of a fan. The liquid spray coming from the nozzle located before the Venturi throat creates a partial vacuum at the entrance of the Venturi. This partial vacuum moves the process gas through the Venturi and the whole dust scrubbing system. The net effect is that Jet Venturi dust scrubber operation is possible without installing additional fan capacities. However, the grade positioning of the scrubbing system results in an additional pressure drop in the connecting ducting that would have to be overcome with a fan. Similarly, installing a dedicated ammonia scrubbing stage downstream of the Jet Venturi stages results in an additional pressure drop, requiring fan implementation. There is an option to dose the acid in the dust scrubbing section, which makes the independent ammonia scrubbing stage obsolete but results in having a single bleed from the scrubbing unit (urea ammonium salt solution) instead of two separate bleeds (urea and ammonium salt solutions).

Based on the above differentiation, it can be concluded that different designs can be developed. Further in the text, a detailed explanation will be given for the base design, which assumes the top positioning of the scrubbing system on a forced draft prilling tower, with a dedicated ammonia scrubbing stage positioned downstream of the dust scrubbing part.

The Jet Venturi scrubbing units are mounted on the air exhaust stacks of the forced draft prilling tower, with each stack having a dedicated scrubbing unit. The scrubbing units comprise three compact stages that progressively treat and clean the off-gas from dust and ammonia contamination. Common pumps for all units are used, circulating the scrubbing liquid per stage. Pumps are located at the grade level, connected to the common downcomer lines used for collecting circulating scrubbing liquids from different scrubbers and as pumps' hold-up volumes. An example of a scrubbing system developed for an existing forced draft prilling tower with six stacks is provided in Fig. 12.

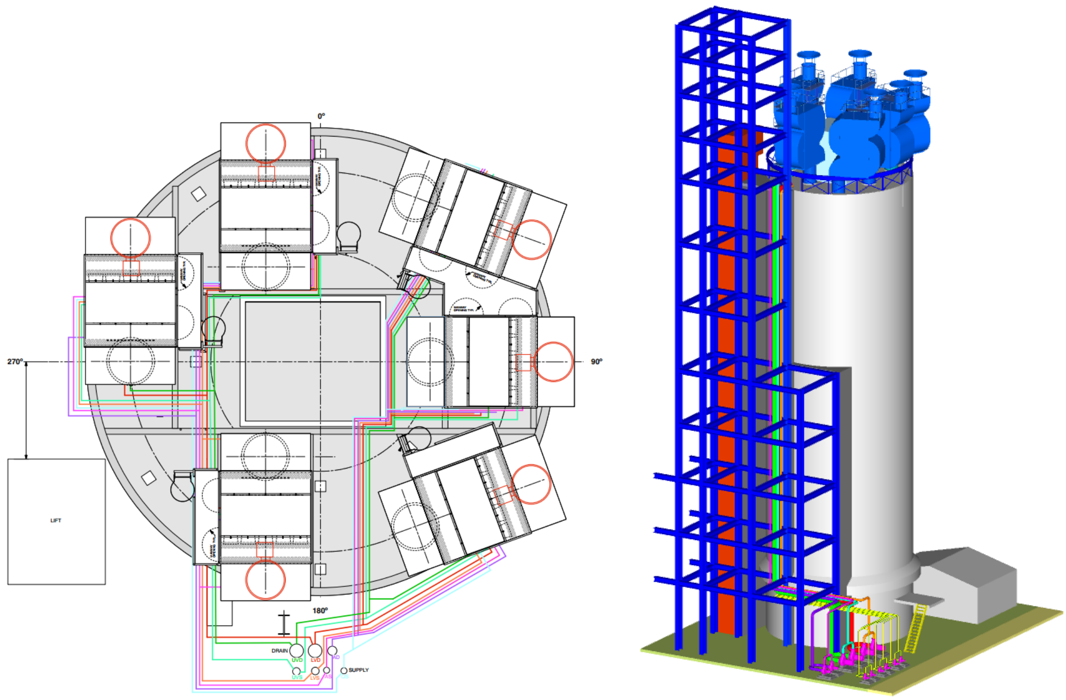

Fig. 12. EVOLVE EMISSION™ Jet Venturi Scrubber installed on top of the prilling tower (revamp case study; top and side view)

To enable preferred positioning on top of the tower, the scrubber design is optimized to reduce its weight. In this manner, it also becomes a viable solution for existing prilling towers, where the maximum allowed additional weight to be placed on top of the tower often proves to be the limiting factor. Reducing the overall weight to be carried by the prilling tower was one of the reasons for developing grade positioning of the pumps and related hold-up suction lines. Additionally, using common pumps for all scrubbers has a positive effect on CAPEX, as the number of units is drastically reduced, especially if redundancy in case of failure is required. On the other hand, to limit the negative impact on OPEX (pumps' power consumption) due to additional height increase resulting from the pumps' grade positioning, the level in the suction hold-up lines is controlled close to the top of the prilling tower.

The three stages of a scrubbing unit (Fig. 13) are (1) quench and primary Jet Venturi scrubbing stage, (2) secondary Jet Venturi scrubbing stage, and (3) acidic scrubbing stage. High-efficiency Mist Eliminators (ME) are placed after each stage, preventing any entrainments from one stage to another and therefore maintaining required concentrations and compositions per stage.

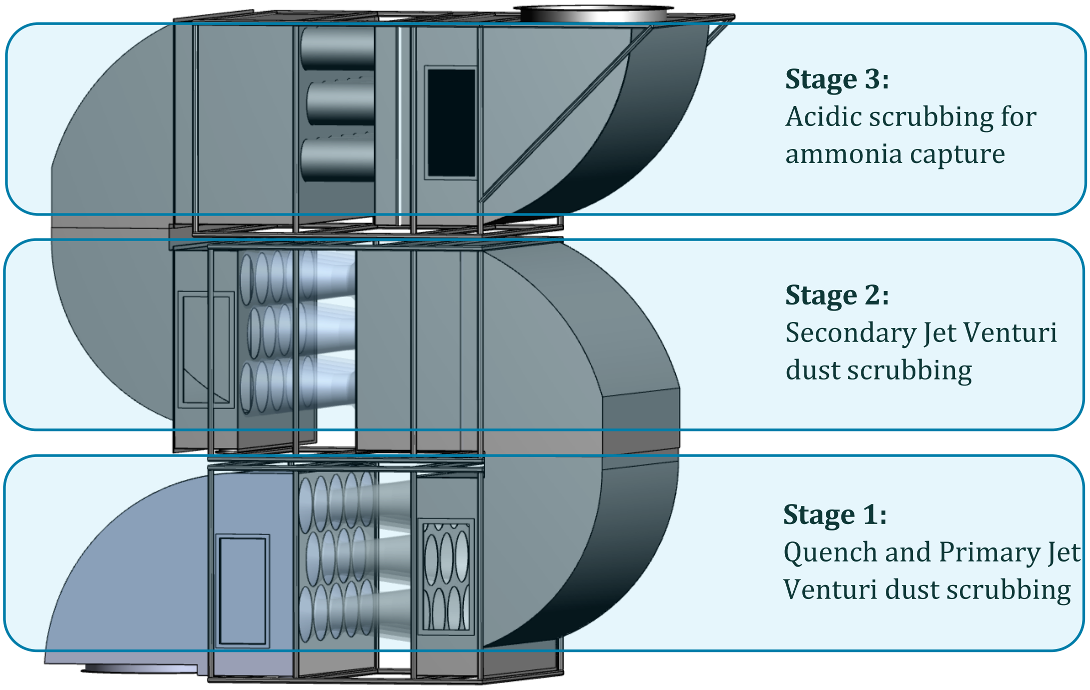

Fig. 13. Jet Venturi Scrubber with indicated stages

4.1.1. Stage 1: Quench and primary Jet Venturi scrubbing

The exhaust air from the prilling tower stack enters the quench stage, where significant removal of coarse urea particulate from the gas stream occurs by spraying recirculating concentrated urea solution (35 to 45 wt-% urea). In the quench section, the gas is cooled down and brought close to saturation. Moreover, the generation of fine droplets is induced and the growth of the otherwise smallest particles, overall resulting in more efficient capture of the submicron particles and condensed aerosols in downstream sections. Non-evaporated quench liquid flows to the downstream located primary Jet Venturi section, is collected in the downcomer line, common for all scrubbers, and partially recirculated back to the quench section using a quench pump.

Downstream the quench section, multiple parallel Jet Venturi elements are installed horizontally on a diaphragm in the primary Jet Venturi section. A jet atomization nozzle is located at the entrance of each Venturi element, spraying the scrubbing solution in the same direction as the airflow. Gas entrained aerosols and fine particulate collide with liquid droplets, leading to high capture efficiencies of particulate, including the submicron dust particles. Moreover, the positioning and design of the atomization nozzle are suited for inducing the off-gas flow through the Venturi element. The scrubbing solution is recirculated and pressurized by a dedicated primary Jet Venturi pump, common for all scrubbing units. The same downcomer line is used as a hold-up volume for both the quench pump and primary Jet Venturi pump, and hence the same scrubbing solution is sprayed in both sections (35 to 45 wt-% urea solution).

This stage is provided with a blowdown of concentrated urea solution recycled back to the urea solution tank of the melt plant. Downstream the primary Jet Venturi section is a mist eliminator for preventing entrainments to the downstream lean solution section. The washing liquid sprayed on the mist eliminator is at the same time the make-up water for the primary stage (due to evaporation and blowdown). Diluted scrubbing solution from the secondary Jet Venturi stage is used as make-up water.

4.1.2. Stage 2: Secondary Jet Venturi scrubbing

The second dust scrubbing stage consists of multiple Jet Venturi elements aligned in parallel and located downstream of the primary section. The same design as in the primary Jet Venturi scrubbing section is applied. This stage collects the remaining submicron particulate in the gas stream. Scrubbing is easier due to additional conditioning of the air stream in the primary Jet Venturi section, as further saturation of the air stream results in further growth of particles through condensation. The secondary Jet Venturi stage uses diluted urea solution as a scrubbing liquid, set in motion via a dedicated secondary Jet Venturi pump. As already mentioned, a fraction of the flow is sent to the primary Jet Venturi section as make-up water, being at the same time the bleed of the secondary Jet Venturi stage for maintaining low urea concentration. The secondary stage receives process condensate from the urea melt plant as a make-up scrubbing liquid (due to water evaporation and for providing make-up for the primary stage). The scrubbing liquid is first used to wash the ME between the secondary Jet Venturi scrubbing stage and the acidic scrubbing stage.

4.1.3. Stage 3: Acidic scrubbing stage

The acidic scrubbing is an optional stage downstream of the Venturi sections for reducing ammonia content in the off-gas stream of the prilling tower. Liquid-to-gas contact is established in slightly inclined horizontal tubes by spraying recirculating acidic solution through the sprayers located at the tubes' inlets. Recirculation is established by the acidic scrubbing pump, common for all scrubbing units. Acid is dosed in the discharge of the acidic scrubbing pump using a dosing pump. The ammonia reacts with the acid and creates the ammonium salt. The salt concentration is maintained in the 10 – 30 wt-% range using the blowdown in the recirculation pump suction, sending the ammonium salt solution out of the battery limits. Similar to the first two dust scrubbing stages, the common downcomer line for all scrubbers is used as a hold-up volume for the acidic scrubbing pump. The acidic scrubbing section receives steam condensate from the urea melt plant as a make-up scrubbing fluid (due to water evaporation and solution blowdown). Before being used as make-up, it is first utilized for washing the ME located downstream of the acidic scrubbing stage.

Downstream the last ME, a scrubber fan is provided for collecting cleaned air and discharging it into the atmosphere. A dedicated axial fan per scrubber is present with a sufficient pressure head to overcome the pressure drop due to the implemented acidic scrubbing stage.

4.2. EXPERIENCE IN PRILLING TOWERS

Once the Jet Venturi scrubbing concept was developed, the next step was to prove it on a pilot scale in a real plant environment. The goal was to test its dust scrubbing capabilities in terms of capacity and scrubbing efficiency, optimize the operational settings, and fine-tune the initial scrubber design and layout. The acidic scrubbing stage was not included in the pilot design as this was regarded as already proven technology. The pilot unit was fabricated in the United States in the workshop of EnviroCare International (ECI) and shipped to Europe, where the tests were carried out in cooperation with a Stamicarbon client. Moreover, all measurements during the testing were conducted by an independent laboratory based in the Netherlands.

The aim was to prove the concept by using a single Jet Venturi layout, i.e., two Jet Venturi elements in series representing primary and secondary scrubbing stages. The pilot facility consisted of four boxes, as numbered in yellow in Fig. 14. These boxes were placed at the inlet and outlet of both Jet Venturi ejectors and contained the mist eliminators, the atomizing nozzles and the hold-up reservoirs for collecting the scrubbing liquid before it is pumped back to the nozzles. The treated gas was extracted from one of the prilling tower stacks, fed through the bottom left duct, further through boxes 1 to 4 and in-between installed Jet Venturis, and sent to the atmosphere via the top left duct. The sampling ports are visible in the middle of the inlet and outlet ducts.

Fig. 14. The pilot unit during fabrication at the ECI workshop with indicated boxes and airflow direction

Before manufacturing the pilot unit, measurements of the actual airflows and velocity profiles in the prilling tower stacks were conducted. In this manner, based on the expected volumetric flow rates of the venturi elements, proper sizing of the extraction ducting and nozzles could be done. This was crucial for maintaining isokinetic conditions at the extraction point in the stack. Moreover, based on the calculated ducting diameters, also the layout of the ducting around the sampling ports could be accordingly designed, fulfilling the prescriptions of the measurement standards. Finally, the pilot unit sizing had to be adapted to fit the available space on top of the prilling tower (Fig. 15).

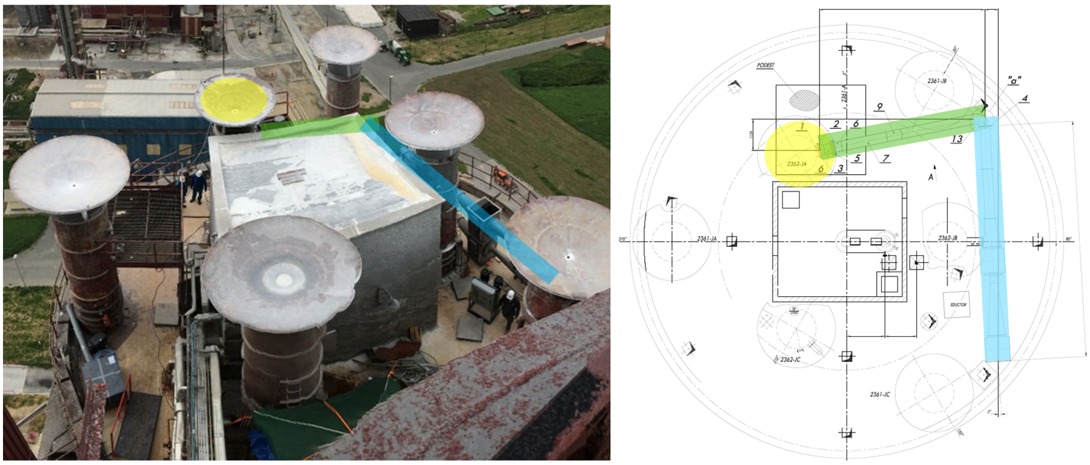

Fig. 15. Positioning of the pilot unit on top of the prilling tower

Field tests were conducted over several weeks. The tests were carried out for different Jet Venturi designs and sizes. Moreover, different atomization nozzles were used together with different scrubbing liquid pressures and different atomization nozzle positioning in relation to the Jet Venturi throat. Of course, considering that changing the above parameters influences the system pressure profile and capacity, the sizing of the exhaust air extraction point had to be adapted accordingly for maintaining the isokinetic conditions. This was validated by comparing the Particle Size Distribution of the dust samples taken from the prilling tower exhaust stack and the pilot unit inlet ducting. Finally, different mist eliminators were tested to determine their optimum design in terms of efficiency and pressure drop.

Conducted tests demonstrated that Venturi elements could handle the airflows as per the base design. Moreover, the design airflows were achieved by solely utilizing the Jet Venturi effect, proving the notion that this scrubbing technology can abate urea dust emission without installing additional fan capacities. What is more important, the dust content of the exhaust air was drastically reduced. Based on the conducted measurements, the expected dust emission from the prilling tower with implemented Jet Venturi Scrubber is less than 15 mg/Nm^3, way below the current European emission limit of 50 mg/Nm^3. The same emission level is expected for the ammonia when acidic scrubbing is implemented, such as below 15 mg/Nm^3.

The scale-up from a single Jet Venturi element to the full-scale scrubbing unit is linear. Moreover, when the scrubbing unit is running, a specific Jet Venturi element can be operational or isolated. In this manner, the operational flexibility of the overall unit in terms of capacity is achieved. Furthermore, the unit capacity can be adjusted by changing the pressure of the scrubbing liquids sprayed at the venturis' inlets. These two mechanisms enable running the scrubbing unit from the turndown capacity to the rated capacity. Similarly, using the same mechanisms, Jet Venturi Scrubber can also be utilized as a revamp tool for prilling towers with limited capacity and cooling duty.

Conducted pilot tests also helped to further optimize the overall scrubbing unit design, eventually leading to the present design as described in Chapter 4.1. Besides the pilot tests, the overall design was further improved based on the outcomes of the performed Design Hazard Study to ensure the safe unit design and conducted CFD analysis for reaching optimal flow patterns and minimum pressure drops.

As mentioned earlier, besides positioning the scrubbing systems on top of the prilling tower also installation on the grade level is possible. This is sometimes the only option for the clients aiming to reduce emissions from the existing prilling towers, where structure strength proves insufficient to support the additional weight of scrubbers and auxiliary equipment. Besides the “S” layout presented in Chapter 4.1, more vertical orientated layouts are possible if the available plot plan proves to be limited.

CONCLUSIONS

To summarize, regarding the MicroMist™ Venturi Scrubber, the new configuration built on the operational experience of two industrial projects will further optimize its environmental and operational performance while decreasing its investment cost. The optimized configuration will be applied at the Volgafert LLC project, which will start production in 2022 in Tolyatti (Samara region in Russia), the Shchekinoazot project in Pervomayskiy (Tula region in Russia) and the EuroChem Northwest-2 project in Kingisepp (Leningrad region in Russia).

Furthermore, the Jet Venturi Scrubber is a novel dust scrubbing technology for prilling towers, proven on a pilot scale in a real plant environment to reduce dust emissions below 15 mg/Nm^3. As no additional pressure drop is generated, the scrubber does not require additional fan capacities for dust emission abatement. Stamicarbon offers tailor-made solutions for existing and grassroot, forced and natural draft prilling towers. The technology is also suitable for debottlenecking existing prilling towers suffering from insufficient capacities or cooling duties. Moreover, acidic scrubbing can be easily coupled to bring ammonia emissions below 15 mg/Nm^3.

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