# Packing performance into separation units

**Claudia von Scala, Sulzer Chemtech Ltd, Switzerland, and Natalia Molchanova, Sulzer Chemtech LLC, Russia,** presents a case study to illustrate the importance of packing to improve plant performance.

Near perfect processing of syngas is key to obtaining a multitude of chemicals and products. The removal of acid gases, such as carbon dioxide ($CO_2$), from syngas prior to the synthesis of ammonia ($NH_3$) is a fundamental process in chemical production plants. This means that the separation equipment needs to deliver maximum performance. To improve its $CO_2$ absorption unit, a manufacturer of technical $NH_3$ selected Sulzer's range of advanced column internals, including the latest column packings.

Syngas is a mixture of carbon monoxide (CO), $CO_2$ and hydrogen ($H_2$), and can originate from different sources. These include natural gas, coal, biomass or almost any kind of hydrocarbon feedstock.

This gas is widely used for the production of a broad range of commodities, such as fuels and $NH_3$. In the latter case, removing $CO_2$ from syngas is necessary to ensure quality products and maximum throughput.

Even the lowest concentration of $CO_2$ can compromise the Haber-Bosch process, which converts atmospheric nitrogen ($N_2$) to $NH_3$ by a reaction with $H_2$ using a suitable catalyst. More precisely, the presence of $CO_2$ deactivates – or poisons – the catalysts, thus affecting the reaction rate and lowering the volume of $NH_3$ produced. If this occurs, processing plants need to replace the poisoned catalysts, incurring additional expenses and downtime.

## Optimising throughput

The key role of $CO_2$ removal in the production of $NH_3$ pushes manufacturers to maximise the efficiency and productivity of this process in order to get the most out of their resources, ensure the quality of their end products

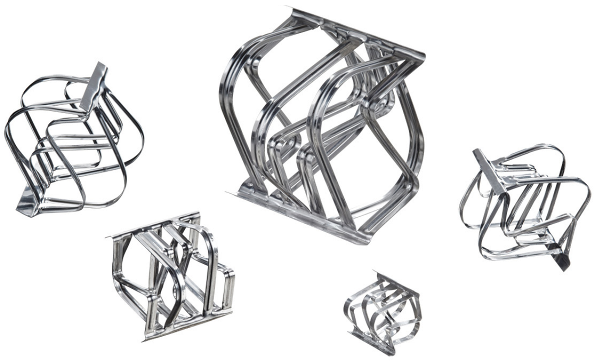

**Figure 1.** Fourth-generation random packings, such as Sulzer's NeXRing$^{TM}$, greatly outperform first- and second-generation rings in terms of column capacity, efficiency and product purity.

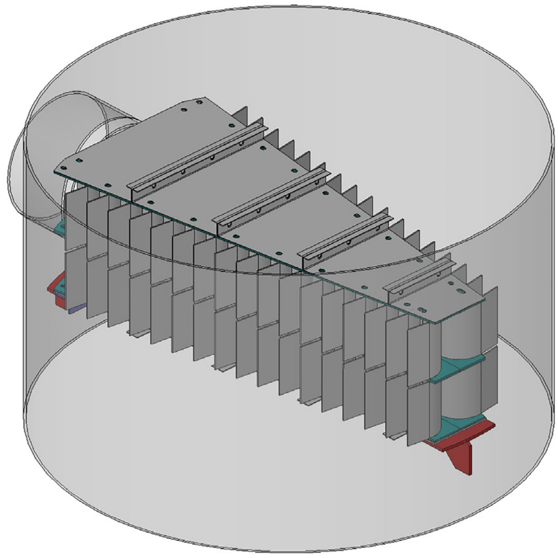

**Figure 2.** The design of Shell SCHOEPENTOETER* radial feed inlet device divides the feed into a series of discrete horizontal streams, promoting the separation process (*SCHOEPENTOETER is a trademark owned and used by the companies of the Shell Group).

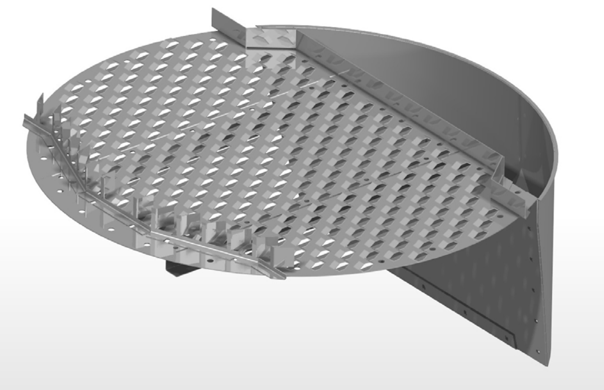

**Figure 3.** The use of fixed valve trays, such as Sulzer's MGV$^{TM}$, in place of sieve trays increases column capacity and efficiency while lowering pressure drop per theoretical stage.

and optimise throughput. This was the goal of a large independent chemical enterprise specialised in the production of nitrogen-based chemicals and mineral fertilizers, such as aqueous technical $NH_3$, $NH_3$ liquor, ammonium nitrate, calcium carbonate and gaseous oxygen.

The manufacturer wanted to increase the capacity of its $CO_2$ removal unit in order to boost the production of technical ammonia from 1500 tpd to 1907 tpd. To achieve this goal, the company contacted Sulzer, which had previously concluded an effective revamp on another unit in the same plant.

Sulzer's specialists started to look at how to improve the existing unit by conducting a thorough inspection to identify possible improvement opportunities in the existing system.

## Take column capacity to the next level

Within the $CO_2$ removal unit, the syngas first passes through an absorber, where hot potassium carbonate promotes the separation process by capturing the acid gas to form bicarbonate. While the sweetened gas feedstock leaves the column from the top, the liquid solution with bicarbonate is directed to a regenerator tower in order to strip the solvent of the absorbed $CO_2$ and reuse it. All six beds of the absorber and all four beds within the regenerator contained Pall Rings, second-generation random packings, as column internals.

However, a number of studies have shown that replacing conventional second-generation packings with the latest fourth-generation ones can increase column capacity by 25 – 35% while maintaining, or even increasing, the overall efficiency and product quality.

These substantial improvements are attributable to the evolution in the design of random packings. From simple, ring-like structures, random packings have turned into complex, wide-open flow-through systems with large surface areas. These changes have been designed in order to create a uniform bed distribution, increase wettability, strength and durability while reducing fouling. Furthermore, newer generation packings can maximise the interfacial area between gas and liquid, as well as high fluid flows.

Based on these considerations, the most effective way to increase the $CO_2$ removal capacity would be by replacing most of the existing random packings with Sulzer's fourth-generation rings, NeXRing$^{TM}$. In this way, the plant could make substantial savings by retaining most of its existing equipment and extending its operational life.

The rings are designed to combine small ring size, which increases efficiency by maximising the surface area for the separation processes to occur, and an open ring structure that optimises capacity by increasing the flow rate within the column. The orientation of the rings on the bed does not influence these properties, resulting in optimal performance at all times.

## Improving performance

In addition, the structure of fourth-generation rings can support high loads and flow rates while reducing pressure drop and foaming. Consequently, these rings are well-suited for $CO_2$ absorbers, where solvents have a strong tendency to foam, affecting the overall column performance.

Sulzer's engineers estimated that the use of fourth-generation random packings would decrease pressure drop by 10% in the absorber and 50% in the regenerator, while substantially reducing steam consumption. The new setup significantly improved the overall separation performance, as the concentration of $CO_2$ at the outlet could be reduced by 30%. As a result, the quality of the output could be increased, reducing the risk of downstream catalyst poisoning.

Two additional measures were taken to improve the overall separation unit. These consisted of the replacement of sieve trays with fixed valve trays, and the substitution of the existing, conventional tangential vapour horn feed inlet attached to the absorber with a Shell SCHOEPENTOETER radial inlet device.

Sulzer's high-performance MVG™ tapered, trapezoidal valves are extruded from the tray deck and oriented parallel to the liquid flow. This design would allow the manufacturer to increase column capacity by 5 – 10%, while also increasing efficiency and lowering pressure drop per theoretical stage.

Furthermore, the upgrade of the feed inlet device would support enhanced separation efficiency and prevent liquid entrainment, even when processing high loads of $NH_3$. Conventional solutions release the feed from a singular opening and separate the vapour and liquid phases using gravitational forces only. On the other hand, the innovative radial system divides the feed into a series of discrete horizontal streams, by means of a number of vanes. As a result, it is possible to dissipate the kinetic energy and momentum of the feed, as well as providing it with centrifugal acceleration to promote the separation of different substances.

## Rapid revamp

The revamp was completed with minimal downtime during two scheduled plant overhauls. In this way, the manufacturer was able to combine the upgrade with parallel maintenance activities and begin using the advanced mass transfer technologies immediately. In between the two planned shutdowns, Sulzer ensured that the $CO_2$ removal unit and the entire plant could continue to operate without any reduction in their capabilities.

This upgrade allowed the chemical manufacturer to boost the capacity of its $CO_2$ removal system by 27%. It was also possible to increase the separation performance by reducing the concentration of $CO_2$ at the outlet by 30%, substantially increasing $NH_3$ quality and minimising the risk of poisoning catalysts. Finally, the manufacturer could decrease pressure drop by 10% in the absorber and by 50% in the regenerator. Consequently, the manufacturer could effectively intensify its $NH_3$ synthesis process, increasing its output.

In addition, considerable reductions in pressure drop within the regenerator allowed the plant to reduce the temperature at the bottom of the column by 4°C. This not only led to a more energy efficient process, but also greatly reduced the risk of thermal degradation of potassium carbonate. As a result, the plant could regenerate most of this chemical, which is reinserted into the $CO_2$ removal loop and then used in subsequent separation processes, optimising its raw material consumption.