A STUDY OF SEPARATION

Doug Little, Koch Ag & Energy Solutions LLC, and Hubert Zey, Koch-Glitsch, LP, USA, describe the use of high-capacity mist eliminators to debottleneck separators in fertilizer production.

Operators of ammonia plants are constantly working to improve the profitability of their production assets. Opportunities to increase the production of existing units frequently provide additional capacity at a lower capital investment than building a new unit. This is especially true of older plants, where it is possible to take advantage of improvements in compressor and catalyst technology to debottleneck a unit. The practicality of incremental expansion usually rests on making the best possible use of existing equipment. If a vessel, such as a vapour-liquid separator, must be replaced to meet the capacity requirements of the revamp, significant costs can be incurred. Frequently the space in the plant is already crowded, making it difficult to locate a new vessel and associated piping. The ability to expand the capacity of an operation by improving its internals can result in significantly lower cost as well as easier turnaround execution.

There are several vapour-liquid separations that are vital to the operation of an ammonia unit and many of these use DEMISTER® mist eliminator technology from Koch-Glitsch. If liquid cannot be efficiently removed from a gas stream, entrainment can cause process inefficiencies, product loss and equipment damage. Therefore, optimally designed mist elimination equipment plays a critical role in the fertilizer manufacturing process. In the ammonia process for example, mist eliminators are typically used in the process condensate separator, the carbon dioxide absorber and solution stripper, syngas compressor suction drums, and the high pressure product separator in the synthesis loop.

Entrainment from the carbon dioxide absorber can lead to carbonate scale on heat exchanger tubes just upstream of the methanator. The scale on heat exchanger tubes can lead to reduction in heat transfer efficiency and excessive pressure drop. Reduction in heat transfer efficiency could result in process rate limitations

Koch Fertilizer, Enid, Oklahoma, US

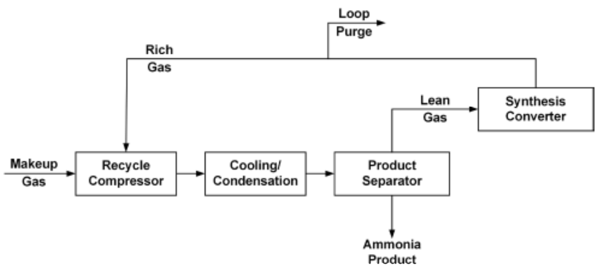

Figure 1. Loop arrangement.

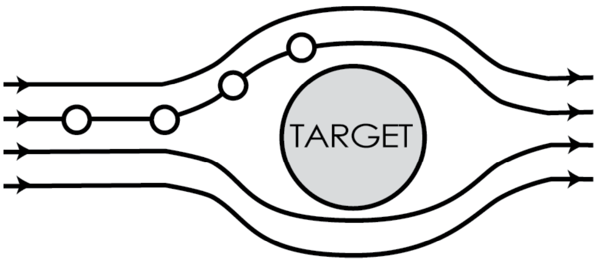

Figure 2. Inertial impaction.

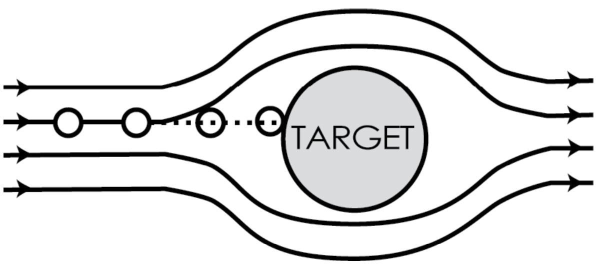

Figure 3. Direct interception.

Table 1. Design values

	English	Metrics
V – design velocity	ft/sec.	m/sec.
ÐL – liquid density	lb/ft^3	Kg/m^3
ρv – vapour density	lb/ft^3	Kg/m^3
K – capacity factor	ft/sec.	m/sec.

until the tubes can be cleaned or replaced. Excessive pressure drop can result in increased power consumption, which affects the bottom line.

Water vapour from the carbon dioxide absorber and the methanator is condensed in the syngas compressor suction coolers and must be removed. Entrainment of liquid into the compressor train can lead to damage to the compressor vanes. Depending on the level of entrainment, this can lead to premature shutdowns to conduct compressor maintenance. In extreme cases, entrainment can lead to the need for compressor replacement, which can have a serious impact on plant production and profitability.

The product separator in the synthesis loop is another important operation (Figure 1). The maximum possible conversion per pass in the loop is limited by the difference between the ammonia concentration in the converter inlet and the equilibrium conversion at the outlet of the last catalyst bed. If liquid is carried over in the separator, the converter inlet concentration is increased, which increases energy consumption and can limit the capacity of the unit.

Mist elimination technology

Most of the mist eliminators used in the fertilizer process separate entrained liquid droplets from vapour using inertial impaction and/or direct interception.

Inertial impaction

As entrained liquid droplets approach the targets of the mist eliminator, the gas flow will divert around the target (Figure 2). The gas applies a drag force on the entrained liquid droplet, encouraging it to divert around the target as well. If the droplet has sufficient inertia, this will cause the droplet to continue towards the target, allowing it to impact on the surface of the targets where it can be coalesced into larger droplets that are large enough to drain against the vapour. This mechanism is velocity dependent; therefore, higher velocity will achieve better efficiency since higher velocity will bring smaller droplets into the targets.

Direct interception

With the same gas flow in mind, consider smaller liquid droplets that are entrained (Figure 3). The inertia of the droplet is not large enough to resist the drag force from the gas, and it will not impact on the surface of the target. However, a certain number of droplets will be carried in gas streamlines that pass within a droplet's radius of a mist elimination target. In this manner, the droplet will touch the mist eliminator surface and be collected. The removal of these droplets is improved by providing more targets, smaller targets and by packing the targets more closely together. Multifilament materials, such as fibreglass, polytetrafluoroethylene and polyester, are typically used co-knitted to create DEMISTER mist eliminators capable of achieving this level of separation.

The below formula, derived from the Souders-Brown equation, is commonly used to determine the allowable velocity through a mist eliminator. The difference between the vapour and liquid densities is the driving force in this equation. The allowable velocity is limited by the hydraulic capacity of the mist eliminator, often referred to as the K factor. The recommended design value of K depends on several system factors, such as liquid viscosity and surface tension, entrainment loading, mesh structure and vessel geometry.

$$V=K\,[(\rho L - \rho v)\,/\,\rho v]^{1/2} \qquad \text{(Table 1)}$$

Through extensive research, the company developed a family of mist eliminators that achieve higher capacities compared to the traditional styles that have been the industry standard for many years. These high-capacity styles are based on improved knowledge about the way internal wire geometry affects capacity and performance. Better drainage of collected liquid from the mist eliminator will result in higher capacity that can help debottleneck separators in the fertilizer process. It is common to retrofit an existing separator with a high-capacity mist eliminator with minimal modification to the existing separator supports. A retrofit also captures significant savings compared to the overall cost of replacing an existing separator with a larger unit.

Case study: Oklahoma, US

Following a partial revamp of one of its ammonia units, Koch Fertilizer in Enid, Oklahoma, was experiencing a capacity limitation in their synthesis loop, which operates at pressures over 2000 psig. Engineers conducted an evaluation that determined the product separator was experiencing carryover of about 0.6 mol% liquid ammonia in the overhead stream. This carryover reduced the achievable conversion per pass in the ammonia converter resulting in the capacity of the plant being limited by loop pressure. The company believed that they would have to replace the product separator to debottleneck the operation.

Before doing so, plant engineers contacted Koch-Glitsch to evaluate the product separator, a horizontal vessel, based on the plant process conditions. Process engineers reviewed the as-built drawing to determine if there were any limitations to the existing support system. Although applying the high-capacity DEMISTER mist eliminator technology to this existing product separator would meet plant expectations, there were other components of the separator that were also evaluated.

Flow distribution is critical in all vapour-liquid separators. As more capacity is expected from existing equipment, traditional design rules for vessel geometry and flow distribution should be reviewed for all components that can affect separation performance.

Figure 4. Elevation view of product separator #106F at Enid plant, showing vapour outlet.

These include the hydraulics of the inlet and outlet nozzles, spacing between nozzles, and liquid levels.

The feed distributor to the product separator as supplied had a certain distribution of holes and slots. Process engineers reviewed the dynamics of this distributor and believed it could be optimised to minimise the amount of liquid entrainment being generated in the product separator. This proved to be a challenge due to the access limitation into the separator. Process and mechanical engineers developed a new distributor design that would minimise the level of entrainment being generated in the ammonia separator and would be practical to install during a short plant outage.

The vapour outlet nozzle (Figure 4) in this compact drum was located at the far end of the DEMISTER mist eliminator. Process engineers believed that this would create local high velocities that could lead to premature re-entrainment, which would limit the capacity of the drum. A flow distribution plate, specifically designed for the process rates, was incorporated into the final design of the mist eliminator. The purpose of this device is to evenly distribute the vapour over the mist eliminator cross sectional area. Therefore, the influence of the vapour outlet nozzle on vapour distribution was minimised.

The equipment was installed in July 2016. After start up, it was determined liquid carryover had been eliminated, which removed loop pressure as a plant limitation. The gas efficiency of the plant was also improved. The separator is operating at a rate over 50% higher than the original plant design without replacing the separator vessel.

Summary

This case study demonstrates how a bottlenecked separator can have a significant impact on overall plant operation and economics. However, separators are often overlooked during process optimisations. The result can be devastating, especially when product losses, mechanical damage to major equipment or corrosion persists, regardless of the efforts to improve other parts of the process.

It was once thought that unlocking more capacity in an existing separator could only be achieved by replacing the separator. However, Koch-Glitsch has shown that a thorough evaluation of process conditions, vessel drawings and inlet/outlet zones is fundamental to solving a separation problem. Existing separators in the fertilizer process can be retrofitted with an appropriate mist eliminator to mitigate symptoms of entrainment or capacity limitations. Frequently, solutions can be implemented with little or no welding required to the vessel shell. Effective analysis can lead to a design that optimises an existing separator to meet the production demands of a plant. WF