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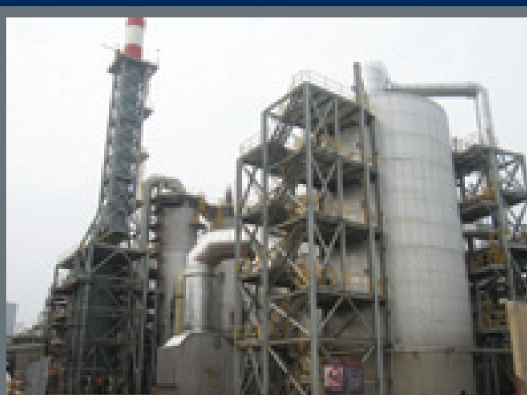

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Acid mist elimination in sulfuric acid plants

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Mist eliminators are essential pieces of equipment in a sulfuric acid plant and will help guarantee trouble free operation. Acid entrained in process gas causes violent and accelerated damage to equipment downstream of the mist formation, and also contributes to harmful emissions to the environment, making proper selection and design of mist eliminators for an adequate removal of acid mists and liquid carryover very important.

In sulfuric acid plants, two main mist eliminators are used: the MaxiMesh®, which are (co-) knitted wire mesh pads or cylinders, generally designed to remove droplets of micrometric diameters in drying towers, and the Fiberbed®, a candle-type mist eliminator capable of removing particles of submicron diameter, usually found in final absorption towers and interpass absorption towers. This article will focus on the latter.

Acid mists, in which liquid sulfuric acid is present in a gas flow, can be formed by two major mechanisms. The first is a result of dynamic shear stress due to contact between the liquid phase and solid surfaces or mechanical drag of the acid by the gas stream, generating droplets of micrometric diameters. The second mechanism involves liquid acid formation through condensation due to thermodynamic changes in the system or chemical reactions in the gas stream, such as acid produced from the reaction between sulfur trioxide and water or the rapid change in temperature due to fast cooling of a SO_3-rich gas, generating droplets of submicron diameters.

When a gaseous stream carrying entrained acid droplets passes through a mist eliminator, the gas moves freely through the fibers and the liquid is captured due to three different capture mechanisms: inertial impaction, Brownian diffusion and direct interception.

When a gas stream carrying liquid particles passes through a fiber, the gas moves freely around the fiber but those particles with sufficient inertia will not follow the gas stream and will impact on the fiber. This mechanism is known as inertial impaction (Fig. 1). The broadest class of impaction devices is wire mesh pads, known as Clark Solutions MaxiMesh®, shown in Fig. 2.

Some liquid droplets will follow gas stream paths that pass at a distance smaller than ½ of the particle diameter from the mist eliminator fibers. When this happens, the particles are collected as the gas passes around the fibers. This effect is called direct interception (Fig. 1).

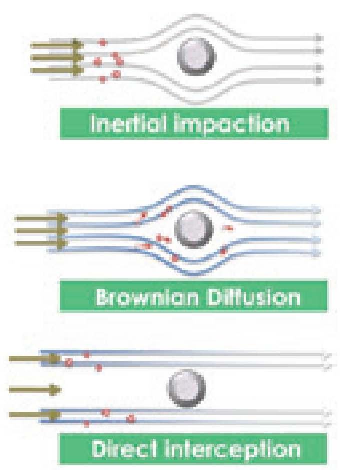

Fig. 1: Droplet capture mechanisms.

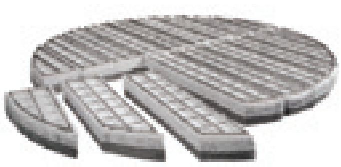

Fig. 2: MaxiMesh® mist eliminator.

On the other hand, particles of submicron scale will neither have enough inertia nor be big enough to be collected by the former mechanisms. However, due to their small size and inertia, they will acquire a random movement—known as Brownian motion—due to the energy transfer caused by their collision with the randomly moving gas molecules. This movement will drive these particles to collide with the mist eliminator fibers (Fig. 1). Brownian diffusion capture will be favorably affected by the reduction in fiber diameter and bed void fraction. Lower gas velocities will increase particle residence time in the mist eliminator bed, which results in a higher probability for the random movement collection, increasing the overall efficiency of the mist eliminator. The Fiberbed®, depicted in Fig. 3, works best in these cases. A typical efficiency curve behavior for each capture mechanism, including Fiberbed® by Clark Solutions, in a in a generic process condition is shown in Fig. 4. Independent of the collection mechanism, once particles are retained by the mist eliminator bed, they will coalesce, leaving the gaseous current free from the liquid.

Fig. 3: Fiberbed® mist eliminators.

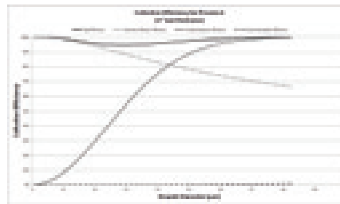

Fig. 4: Typical collection efficiency for different capture mechanisms.

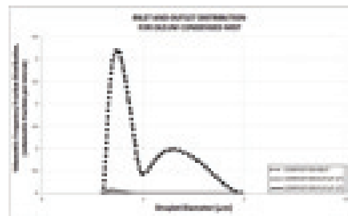

Fig. 6: Inlet and outlet distribution for condensed mist with oleum.

Mist eliminators have geometry, materials and construction details that are designed to retain a certain range of droplets with a certain efficiency, to precisely fit the process they're designed for. Fiberbed® eliminators are often used in the absorption towers because conditions at the inlet of the tower make formation of sulfuric acid (either by chemical reaction between water and SO_3 molecules or by condensation of sulfuric acid molecules) likely to occur, generating a substantial amount of fine acid mist. This condensation is even finer when the plant is operating an oleum tower. The fiber density and layer width of candle-type fiber filters such as Fiberbed® are specially designed to improve the Brownian diffusion capture mechanism and collect this mist, and are responsible for extending the plant's life and uptime.

Droplet size influence

The average estimated droplet size distribution of sulfuric acid mist generated at an Interpass tower of a typical 3/1 absorption plant is shown in Fig. 5. However, numerous factors and process conditions can alter the droplet distribution, such as proper air drying, leaky water or steam piping, poorly designed or installed acid distributors and low packing heights, increasing the liquid load on the mist eliminators.

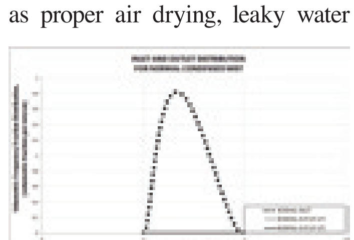

Fig. 5: Inlet and outlet distribution for condensed mist without oleum.

One of the most frequent unnoticed occurrences that shifts the droplet size is the presence of mist due to oleum production. Because oleum is formed through a chemical reaction between sulfuric acid and SO_3 at low temperatures, many submicron-sized droplets are formed during condensation when an oleum tower effluent stream comes in contact with the hot gas main stream flowing into the Interpass tower, distorting the Gaussian-like estimated droplet distribution curve for the absorption tower. The result is an estimated wavy distribution which peaks at very small diameter sizes, as shown in Fig. 6.

Mist elimination design

As discussed, Fiberbed® mist eliminators are designed to capture submicron particles that behave in Brownian motion. However, it is important to select the right fiber diameter, bed density, bed thickness and bed layers to efficiently remove acid mist content in the expected distribution range. Not only efficiency must be taken into account, but also available pressure drop during clean and dirty plant conditions. Three-inch beds will generate on average 50 percent more pressure drop than two-inch beds, as pressure drop is proportional to bed thickness given all other variables are constant. An estimated efficiency comparison between two- and three- inch bed thicknesses is shown in Fig. 7.

Fiber bed mist eliminators such as Clark Solutions Fiberbed® are a unique class of equipment. Unlike many other mist eliminator devices, they are designed and built to provide nearly 100 percent efficiency in all range of particle sizes. This performance can only be achieved with strict quality control and fabrication standards. After manufacturing, a dry pressure drop plot (Fig. 8) followed by a hot air thermography (Fig. 9) will ensure that the equipment is properly manufactured and will perform to the expected levels.

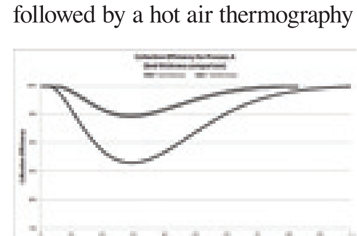

Fig. 7: Total collection efficiency comparison for 2" and 3" bed thicknesses.

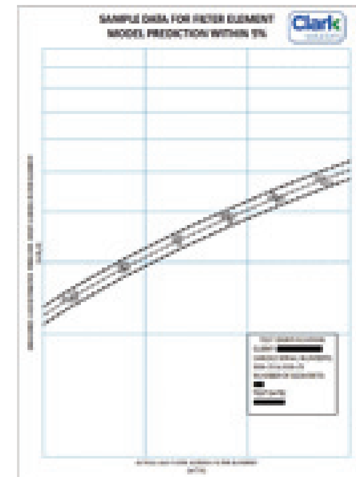

Fig. 8: Online dry pressure drop plot.

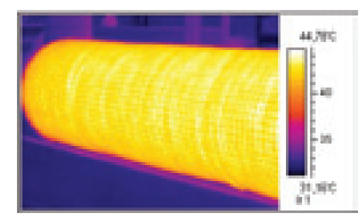

Fig. 9: Thermography to evaluate filter bed homogeneity.

Conclusion

In Fig. 7, where efficiencies were measured for beds with similar characteristics with exception to thickness, it is possible to assess that a three-inch bed thickness brings much more efficiency, which results in an almost flat outlet distribution shown in Figs. 5 and 6, whereas a two-inch bed thickness shows an inefficiency for oleum production, resulting in a small peak outlet in Fig. 6, which may be observed in a stick test or in acid draining at downstream equipment.

For plants without oleum, a two-inch bed thickness may bring a better trade-off in efficiency and pressure drop, becoming a better option in situations with lower acid mist generation or in conditions with higher droplet diameters.

Finally, when observing acid content downstream from towers, it may be necessary to inspect and evaluate the plant, considering dry tower inefficiency, water leaks and bad acid or gas distributions inside towers, as well as other problems. Clark Solutions is available to conduct such inspections.

For more information, please visit www.clarksolutions.com.br. ❑

Reference: Louie, Douglas K. "Handbook of Sulphuric Acid Manufacturing," 2005.


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