# A Mist Opportunity

Mist eliminators are often utilised in the fertilizer industry to prevent mist carryover and reduce air pollution and loss of product during the production of various fertilizers and precursors such as sulfuric, phosphoric and nitric acids. Applications in ammonium nitrate operations include the purification of steam from the neutralisation and evaporation processes, removal of ammonia and ammonium nitrate from the prilling operations, and sulfur dioxide discharge reduction from sulfuric acid plants.

There are different categories of mist eliminators, such as vane or baffle-type, mesh pads, and fibre bed or candle filters, each with unique mist collection mechanisms.
Therefore, selecting the appropriate mist eliminator type for a process requires careful evaluation and comparison of various factors. Understanding how mist droplet collection mechanisms operate helps distinguish the different types of mist eliminators:

- Impaction – applicable for larger droplets, 2 microns in diameter and greater, that move along with the gas stream until the particle comes to an obstacle, such as a fibre in the filter media. The gas stream flows around the fibre, and the large diameter particle, controlled by its momentum, continues its original trajectory and 'impacts' onto the fibre.
- Interception – applicable for smaller droplets, between 0.5 – 3 microns in size. The particle has less momentum, and the centre of gravity path goes in the same direction as the gas around the fibre. However, the particle has a finite diameter, and the edge of the particle is 'intercepted' by one or more fibres and is collected.
- Brownian diffusion – applicable for sub-micron mist droplets that have very little mass and therefore little momentum, so the mean path of these particles follows the gas stream around the fibre. However, the sub-micron particle movement mimics the random movement of a

**Marilia Davidson, Damion Adams, USA, and Ali Goudarzi, the Netherlands, CECO,** explain how droplet collection mechanisms operate and help distinguish different types of mist eliminators.

gas molecule (Brownian motion), causing deviations away from the mean stream. With a given fibre diameter, residence time, gas velocity, bed depth, and packing density, these deviations cause the submicron particle to collide with the fibre and be collected.

## Mist elimination devices

Vane mist eliminators offer an efficient and cost-effective solution for mist collection and operate on the principle of inertial impaction. They consist of parallel corrugated sheets, often referred to as vanes or chevrons, which are held at a fixed distance apart to create a sinuous flow path for the mist-laden gas. As the gas navigates through the twists and turns of the vane, the heavier liquid droplets cannot change direction as quickly as the gas due to their momentum. This difference in inertia causes the droplets to impinge on the vane surfaces, where they coalesce into larger drops and eventually drain away.

**Figure 1.** The fibre bed filter element can be a standing type (left), or a hanging type (right).

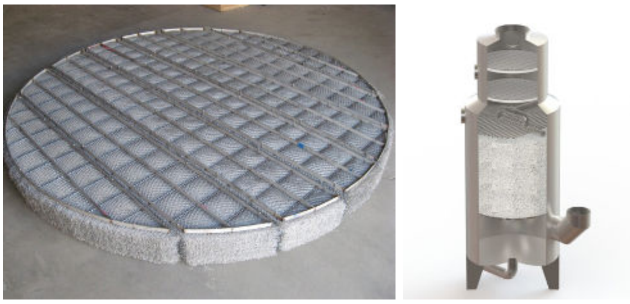

**Figure 2.** Mesh pad mist eliminator.

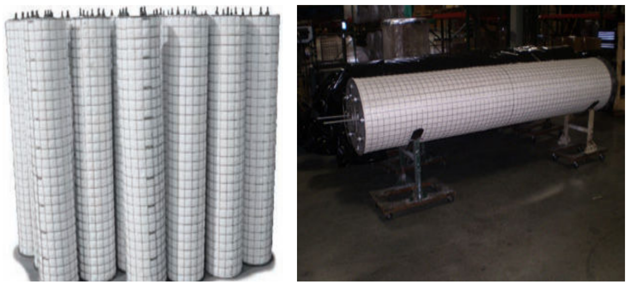

**Figure 3.** Fibre bed mist eliminator.

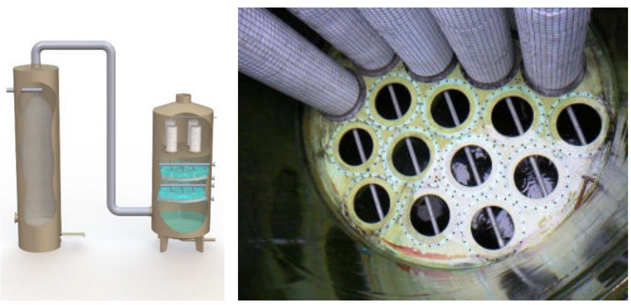

**Figure 4.** The existing system.

Standard vanes are particularly useful in applications where fouling is a concern. Their robust design and ability to efficiently separate droplets as small as 10 – 40 $\mu$m at low-pressure drop makes them suitable to handle heavy-particulate environments upstream of a more efficient polishing filter.

Mesh pad mist eliminators are made of layered knitted mesh that is individually crimped to the desired height to maintain density and specific surface area. The mesh arrangement has a high open area for gas flow to reduce pressure drop and a fine wire surface area to increase droplet collection efficiency. Mist droplets collide on wire surfaces (impaction and interception collection mechanisms) and/or coalesce together to form larger droplets, which then drain to the bottom of the pad by gravitational force.

Fibre bed filter elements are typically constructed in annular cylindrical form (candle-style filters) with outer and inner screens where the fibre bed filter material is placed between the two screens. Particle-laden gas passes horizontally perpendicular to one side of the fibre bed and cleaned gas exits from the opposite side.

These filters remove liquid mist, droplets, and soluble particulates from a process air or gas stream. They excel at high efficiency, up to 99.9 at wt % removal of fine aerosols and particulates as low as 0.2 microns and may also be used to collect insoluble solids. They are particularly useful for preventing contamination of subsequent processes and corrosion damage to downstream equipment, eliminating undesirable atmospheric emissions, and valuable product recovery.

The fibre bed filter elements can be a standing type, which rests on a tube sheet, and gas flows from inside the filter to the outside, or a hanging type, where filters are suspended from the tube sheet and gas flows from outside to inside (Figure 1).

## Fibre bed mist eliminators

CECO's Graded Bed$^{TM}$ media bed is constructed of multiple layers of different media types. Specific media layers are selected to improve flow distribution and solid particle depth loading on the inlet side and higher-density media to achieve a high collection efficiency of sub-micron particles on the downstream side. This technology provides performance for sub-micron droplets (~ 0.2 – 1 micron range), with lower pressure drop, while extending the filter's lifetime.

Filters like the TWIN-PAK® by CECO are designed to increase capacity by ~ 60% or decrease pressure drop by ~ 40% compared to a single wall filter. They utilise smaller and less expensive filter systems and the inner filter is nested inside an outer filter, both equal in design, taking advantage of the unused space inside the standard filter element and increasing the effective surface area for mist collection. This design is also convenient for retrofit projects where increased throughput is desired without vessel modifications since the TWIN-PAK filters are often installed on the existing tube sheet.

**Figure 5.** Mist eliminator designed by CECO.

**Table 1. AN Prill Tower initial loading, target process parameters and outlet specifications.**

| Parameter | Value | |
|---|---|---|
| AN dust load | 300 mg/$Nm^3$ | |
| Ammonia load | 120 mg/$Nm^3$ | |
| New/increased gas flow rate | 316 000 $m^3$/hr | |
| Allowable pressure drop | 550 mm W.C. (across total system) | |
| Outlet AN | < 2.5 mg/$Nm^3$ | |
| Outlet ammonia | <0.7 lb./h or < 0.32 kg/h | |
| Opacity: | < 5% | |
| Particle size distribution: | Particle size | % by mass |
| | < 0.1 | 3 |
| | 0.1 - 0.3 | 9 |
| | 0.3 – 0.5 | 13 |
| | 0.5 - 1 | 30 |
| | 1 - 3 | 30 |
| | >3 | 15 |

**Table 2. Particle removal efficiencies.**

| Particle size (micron) | P3 Media (before retrofit – conventional filter) | P2 Media (after retrofit – TWIN-PAK filter) |
|---|---|---|
| <0.1 | 99.93% | 99.96% |
| 0.1 - 0.3 | 96.02% | 97.78% |
| 0.3 - 0.5 | 95.82% | 97.92% |
| 0.5 - 0.75 | 98.54% | 99.37% |
| 0.75 - 1 | 99.24% | 99.68% |
| 1 - 3 | 99.82% | 99.93% |

## Mist eliminator selection: design factors

It is important to consider the size, distribution, and characteristics of the droplets to be removed, as well as gas flow rate, pressure drop, and liquid load in the gas stream. These factors help determine optimum and efficient performance.

Gaseous contaminants in phosphate fertilizer processes include phosphorous-containing particulates, fluorides, and heavy metals. In nitrogenous fertilizer processes, nitrogen-containing particulates and ammonia are the predominant contaminants.

During fertilizer production, aerosols and mists with varying droplet sizes are created due to chemical reactions, thermodynamic changes, or mechanical shearing. It is often difficult to get a droplet size distribution in the design phase of a new project, but fortunately, pollution control equipment targeting specific fertilizer applications has already been established as an industry standard over the years.

Most often in retrofit projects, there is an allowance for the maximum pressure differential between the inlet and outlet of the mist eliminator that can be tolerated. This can significantly impact the selection and design of a mist eliminator while targeting for the highest possible mist removal efficiency. The pressure drop directly correlates to velocity and can be influenced by many factors, including solid and liquid loadings and varying gas and liquid densities.

The velocity of the gas is a critical design parameter. Vane-type mist eliminators are more suitable for high gas velocities, up to approximately 1950 fpm, and fibre bed mist eliminators are more suitable for low velocities, up to 45 fpm.

Similarly, the liquid handling capability varies among different mist eliminators. High liquid loads, for example, can quickly flood a fibre bed filter and negatively impact its mist collection performance. Above the liquid load, droplets go through the mist eliminator and re-entrain the gas stream.

## Case study

A large fertilizer production company in the US approached CECO Environmental to support a retrofit project to increase high-density AN prilling capacity by 20% without costly CAPEX.

The existing system consisted of a dual-stage vertical scrubber with a heavily irrigated mesh pad and candle filter to remove ammonia gas, sub-micron AN from the gas stream and to control opacity from the prill tower exhausts.

The first stage mesh pad was sprayed at the top and bottom with nitric acid solution to remove ammonia gas in the form of aqueous ammonium nitrate, and to remove prill particulates greater than 2 microns.

The second stage had a higher efficiency and targeted particulates smaller than 2 microns in size. Candle filters were the last step in the filtration system and provided the highest removal efficiency, collecting submicron particulates, which are often the culprits of visible stack opacity. All the mist eliminators were irrigated with process water to solubilise and dissolve the trapped AN particulate to prevent pressure buildup.

The new design is comprised of filters packed with graded bed media featuring a double filtration design, utilising the inner annular filter space and providing more surface area while keeping the original filter's outside diameter and length intact.

Before the retrofit, 62 standard filters were installed into the 6.4 m diameter vessel. After the retrofit, 50 filters were installed, and 12 openings on the tube sheet were capped.

The new design significantly improved the efficiency at every particle size exclusion.

In addition to the filter changes, the spray system was redesigned to provide extra spray locations, which improved the washing of AN dust upstream of the filters, preventing rapid solid buildup and, as a benefit, reducing maintenance shutdowns.

## Results

The modifications enabled the system to be in full compliance with ammonia, AN dust, and opacity emission requirements while minimising OPEX through a list of benefits highlighted below:

- Lower quantity of filters.
- Reduction of fan power consumption due to lower pressure drop.
- Extended filter service life (two additional years) due to lower pressure drop when combined with better washing.

**Table 3. AN Prill tower exhaust conditions before and after retrofit.**

| Parameter | Before retrofit | After retrofit |
|---|---|---|
| AN dust content target < 2.5 mg/Nm$^3$ | 5 – 6 mg/m$^3$ | < 2.5 mg/Nm$^3$ |
| Ammonia content target < 0.7 lb./h or 0.32 kg/h | 0.5 lb./h or 0.23 kg/h | 0.4 lb./h or 0.18 kg/h |
| Opacity target < 5% | 9% | < 5%, with no visible plume emissions |
| Total pressure drop target 450 mm W.C. Maximum = 550 mm W.C. | 350 mm W.C. across the fibre bed filters. 550 mm W.C. total pressure drop, max. | 300 mm W.C. across the fibre bed filters. 420 mm W.C. total pressure drop. |

## Conclusion

Mist eliminators are widely used during the production of fertilizers to remove liquid droplets from gas streams, which are often sources of pollution or nuisance mist damaging downstream equipment. Vane, mesh pads and fibre bed filters are the three main categories of mist eliminators, each operating via impaction, both impaction and interception, and Brownian diffusion mechanisms, respectively. A careful consideration of design factors, including, but not limited to, droplet size and characteristics, gas flow rate, pressure drop, and liquid load, can provide significant savings in the operational costs of a process under retrofit planning with no changes to existing equipment. WF