A Matter of Mist

Graeme Cousland, Begg Cousland, UK, discusses the importance of appropriate mist elimination solutions for sulfuric acid plant operations.

The production of sulfuric acid, and also the handling and storage of it and other products such as liquid SO_3 and oleum, is intrinsically linked with the generation and entrainment of liquid particles ranging in size from droplets to sub-micron aerosols, as a result of the process. These acid mist particles are an obvious air pollution problem and health and safety concern, but they are equally a major operating factor within the process. The selection of appropriate mist elimination equipment for each stage where it is required is vitally important for achieving the production capacity of the plant, as well as for the optimum protection of other equipment within the process, and the minimising of stoppages and maintenance interventions.

Mist formation

Solid particulates can act as a nucleus for the formation of mist particles. Most mist is formed in the following two ways:

Water-based mist

The physical limit of drying is 3 mg/ft^3 of gas (as H_2O) = 16 mg/ft^3 as H_2SO_4. Residual water vapour will react with SO_3 in the gas phase and condense into mists as soon as the gas temperature is below the acid dew point.

If the sulfuric acid production process is fed from burned sulfur, and the sulfur contains hydrocarbons, then the water vapour emitted will react with SO_3 in the gas phase and condense into mists when the gas temperature is below the acid dew point.

Table 1. Typical measured acid mist loads and sizes

Plant/Process	Tower	Total acid load mg/Nm^3	>3 μm %	1 – 3 μm %	<1 μm %
Sulfur burning	DT	500 – 750	80	10	10
Smelter off-gas Spent acid recovery	DT	750 – 1000	60	20	20
Sulfur burning SA Smelter off-gas SA	AT	2000 – 3000	30	30	40
Sulfur burning DA Smelter off-gas DA Spent acid recovery DA	IAT	2500 – 3000	30	30	40
Sulfur burning DA Smelter off-gas DA Spent acid recovery DA	IAT after bypass oleum T	3000 – 4000	25	25	50
Heat recovery process DA	IAT	10 000 – 25 000	10	30	60
Sulfur burning DA Smelter off-gas DA Spent acid recovery DA	FAT	750 – 1500	40	30	30
Wet catalysis	AT	30 000 – 80 000	10	30	60

Key: SA = single adsorption; DA = double absorption; DT = drying tower; AT = (single) absorbing tower; IAT = intermediate absorbing tower; FAT = final absorbing tower.

Figure 1. Some examples of drying tower mist eliminators.

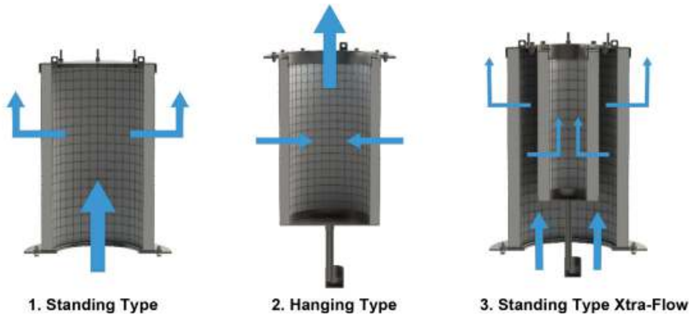

Figure 2. Some examples of candle filter design types.

In non-ferrous metallurgical plants, SO_2 and SO_3 gases are generated in the smelter. The SO_3 can react with H_2O in a weak acid gas cleaning tower downstream and that acid will later condense into small mist particles in the drying and absorbing tower, if it is not continuously and efficiently removed by wet electrostatic precipitators or by other means before the sulfuric acid section.

In the wet process, H_2S burning gives H_2O vapour, which combines with SO_3 to form a high amount of fine mists.

Shock cooling mist

Even if no water was present, mists are formed thermodynamically in the lower part of an absorbing tower as the gas enters the tower at more than 200°C and acid is recirculated at approximately 70 – 80°C. The vapour pressures of H_2SO_4, H_2O, and SO_3 change quickly, and H_2SO_4 mists are generated.

An oleum tower operates at a low temperature (40°C) to promote the absorption of SO_3 into oleum. These towers are installed with full flow or on by-pass.

Large amounts of fine mist (<1 μm) are generated on bypass because:

- Severe quench cooling occurs.
- The partial pressure at equilibrium of SO_3 vapour is much higher than normal in an intermediate absorbing tower (IAT) or final absorbing tower (FAT).

Particle size distribution of mist

One can evaluate the actual particle size distribution (PSD) of the liquid particles in a gas stream in a sulfuric acid plant by isokinetic sampling of the gas stream through a probe attached to a vacuum pump, which passes the gas through a series of plates or bottles to collect and grade the amount of mist in different size ranges. Measurement of particles below 0.5 μm (and certainly below 0.3 μm) can be unreliable due to the semi-gas/semi-liquid nature of such 'aerosols'. In addition, the mass of liquid in the gas can be measured by weighing a time-controlled sample taken out through the probe into a single collection stage.

Begg Cousland has amassed a significant amount of data that helps it to understand in detail the influence of the different mist formation effects mentioned earlier in different sulfuric acid plant designs and process modes. Among the main factors are the type of acid distributor, the acid distribution rate, the acid temperature, the gas temperature, the tower packing concept, and the velocity through the tower packing. In a simplified, summary form, the values shown in Table 1 reflect the company's general experience in these cases.

These values are mostly based on operating conditions in the early stages of the life of the plant. As a plant gets older, and process conditions change, so do the mist sizes and loads.

Drying towers

When a drying tower is not equipped with a filter system, or if the filter system is not operating correctly, H_2SO_4 is entrained downstream. It will have a detrimental effect on the gas blower if the drying tower is under suction and will cause problems to the first catalyst bed. In addition, it passes into gas phase and then condenses into sub-micron mists in the downstream absorbing tower, increasing the 'normal' mist load.

There are a range of mist elimination options possible for drying towers, influenced by the plant type and expected range of gas flows including the following:

- Knitted wire mesh pad demisters are the simplest and have the lowest pressure loss. They can be installed horizontally (Figure 1), conically, and vertically, with a pad thickness of 150 mm and have a base efficiency of 100% removal >5 μm. Begg Cousland has designed and supplied two vertical demister installations for drying towers in plants designed by Outotec, where the vertical demisters are quickly accessed through doors on the roof of the tower, avoiding the need to enter the tower itself when removing or installing (Figure 1). It is a definite safety feature, which also permits one of the existing users to remove and wash the meshpads on a regular basis to minimise the impact of solids blockage.
- Knitted wire mesh pads with some layers being wire co-knitted with glass or polytetrafluoroethylene (PTFE) fibre yarn are able to increase the base efficiency to allow

virtually 100% removal >2 μm. However the fibre adds to the pressure loss.

- High velocity, short, standing, cylindrical candle filters are the other common type of filter used (Figure 1). Like meshpads, they mostly rely on impaction for their efficiency. In fact, some of these candle filters have the 'fibre bed' partly or completely composed of knitted or co-knitted mesh layers. Others have partial or complete fibre beds made of large diameter glass fibres, and the collection efficiency below 3 μm and pressure loss will vary according to the fibre bed type, but all will offer 100% removal >3 μm. Impaction works because the larger droplets of acid cannot change direction within the fibre bed when approaching a wire or fibre. This usually means that if the gas flow is reduced below 60% then the droplets move too slowly and may not be fully collected. When there is a 150 mm thick horizontal demister meshpad in the gas path, it works efficiently down to 30% of gas volume flow, unlike a cylindrical mesh or fibre bed, which has 50 mm or less mesh thickness.

Intermediate absorbing towers

Protecting the downstream equipment is the key parameter when specifying the type of mist eliminator to use at the exit of an intermediate absorbing tower. Immediately after this tower is the cold gas-gas heat exchanger, an extremely expensive and critical item. If it corrodes or blocks due to insufficient acid mist removal, then production capacity and maintenance/replacement budgets are affected.

In modern plants, this tower is equipped with high efficiency, long, cylindrical candle filters, which collect droplets and sub-micron mist due to the Brownian Diffusion mechanism. Providing the gas velocity is below 0.25 m/sec. in the fibre bed, and providing the fibre bed is uniform, was densely made with the smallest fibre diameters possible, and has sufficient bed thickness to handle variations in mist load, solids presence, and saturation, then it should, as a minimum, remove acid particles to below 20 mg/Nm^3 in the exit gas. This is the same emission level, which should be guaranteed to be invisible when exiting a stack to the atmosphere.

These Brownian Diffusion mist eliminators can be installed standing on a tubesheet with inside to outside gas flow, hanging through holes in a tubesheet with outside to inside gas flow, or with two concentric fibre beds (Xtra-Flow) in either standing or hanging mode, with a combination of gas flow paths increasing the available surface area by approximately 30% (Figure 2).

The Begg Cousland TGW15 fibre beds use the smallest possible glass fibre diameter for optimum capture of sub-micron mists. Brownian Diffusion mist eliminators generally have a substantially longer life than high velocity types and many of the company's installations did not need to be replaced for more than 20 years, with the longest achieving over 30 years' service.

Although the relatively low gas velocity through the fibre bed means there are large numbers of long filters needed in a tower top, they are able to be guaranteed to work efficiently within a gas volume range of 30 – 100%. The efficiency may still be achieved below the 30% value, providing there is sufficient fibre bed resistance (fibre density and acid saturation).

Figure 3. Hanging type mist eliminators being retrofitted with top meshpads.

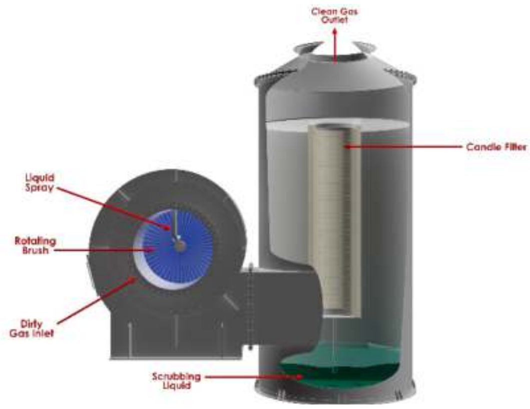

Figure 4. Becoflex BFCF schematic.

Heat recovery technology: intermediate absorbing towers

There are different technologies available for the production of medium and high pressure steam in a sulfuric acid plant, which involve the use of sulfuric acid to contact the gas at the start of the first absorption stage. These technologies can use a single two-stage tower or two tower stages in series. The acid mist load generated, which then reaches the mist eliminators, is five to ten times greater than usual in an IAT, and the majority is mist or sub-micron mist.

Traditional Brownian Diffusion candle filters mostly have a bed thickness of 50 mm. However, when faced with such a volume of acid mists, it helps efficiency to increase the bed thickness to 63 mm or even 75 mm. The impact on gas flow resistance of this acid volume is significant and substantially more filters are needed to operate at economic pressure loss values, which also has the benefit of minimising the risk of flooding and re-entrainment of acid droplets. In cases where the mist eliminator design was found to be incompatible with the actual operating conditions, vis-à-vis mist load, Begg Cousland was able to improve the performance, for example by adding small meshpads to the top outlets of hanging type filters (Figure 3).

Final absorbing towers

The FAT mist eliminators are there for environmental protection reasons with the requirement to meet the applicable emission limit by measurement (e.g. <20 mg/Nm^3) or by opacity. The opacity method has an inherent blind-spot concerning the non-visibility of spitting droplets. A visible emission from a sulfuric acid plant stack will be either mist (<3 μm) or condensed SO_3, or a combination of those, while entrained acid droplets go undetected until they fall on solid ground. Worth noting is that where a downstream scrubbing tower or electro-static precipitator (ESP) is installed for pollution control reasons, the FAT may simply have a meshpad or high velocity mist eliminator.

The mist eliminator design depends on the operating regime of the sulfuric acid plant and the FAT's design and performance. As previously stated, the Brownian Diffusion type mist eliminators are able to cope with most fluctuations in gas volume, inlet acid load, and particle size. In contrast, the high velocity type rely on relatively stable gas flowrates and process conditions to maintain consistent SO_3 absorption, with minimum mist formation in the tower.

Solids and corrosion

The life of a mist eliminator is primarily determined by the avoidance of insoluble solids and corrosion.

Insolubles (e.g. dust, sulfur, ferrous sulfate) and some others (e.g. nitrosyl crystals and other chemically formed salts) can block the fibre beds or meshpads and interfere with the normal passage of gas and the normal drainage of acid. The pressure loss increases to an unacceptable point and the filter is washed or replaced, to restore efficiency and pressure loss.

Corrosion can take different forms:

- Of the meshpad or grids (metal).
- Of the filter structure or anti-reentrainment layers (metal).
- Of the fibre bed (glass) or meshpad (high silicon alloy) when hydrogen fluoride is present.

Some of these instances can be avoided by a different choice of materials (alloy metal or carbon fibrebed), or by improved maintenance procedures. In more harsh environments, however, there may not be the luxury of choice.

Storage

When sulfuric acid or other products, such as oleum, are produced, they are stored in tanks, which have vent systems. When gas (fume) exits the tank vent, it should be cleaned or filtered to prevent a white haze of mist being visible. Old technology used a simple pipe with a co-current spray to hydrolyse the SO_3 and the mist formed as a result goes into a mist eliminator.

There is an equally simple, but technically superior, system available, which replaces the fan and sprayed pipe with a special brush inside a fan casing, which is sprayed while it rotates, and acts as both impeller and gas washer. This Begg Cousland Becoflex BFCF unit incorporates a Brownian Diffusion candle filter as the second stage (Figure 4) and completes all of this with minimised liquid flow and invisible emission.

Conclusion

There is no doubt that the role of a mist eliminator is critical to the correct performance and life of a sulfuric acid plant and its gas contact components. The process variations and acid particle range generated as a result demand an equal range of mist elimination solutions to suit the efficiency and pressure loss needs of each tower. For each plant, there will be a specific balance of performance and maintenance. However, assuming there are no absorption problems, there is no reason why today's plants should have visible acid emissions. WF