Applying the Right Mist Elimination Physics

Separating liquid droplets from a gas stream loaded with mist or from a gas-liquid stream under high pressure, the selection of the right technology is essential to achieve the desired performance and specification. The article talks about some scenarios when mist elimination becomes crucial in petrochemical and chemical industries, and gives an insight into many innovative methods and technologies that have been proven as a low cost, highly versatile and efficient while executing mist elimination and allied separation process.

Computer-aided design of a mist eliminator - Image Courtesy Sulzer

During Mist Elimination, it is very important to understand and apply the physics properly within various applications, e.g. a vane-pack may work properly under normal atmospheric conditions, but in a high-pressure hydrocarbon system, the physical properties of the system completely change, thus rendering conventional mist elimination devices practically useless at times. Also, in many debottlenecking and revamp cases within the gas, petrochemical and chemical industry, one comes across situations where capacity and separation performance are limited by the type of separation device chosen. This calls for innovative technologies; say for instance, separation of liquid droplets from the gas-liquid mixture by imparting higher centrifugal forces.

Liquid entrainment in a process gas stream can be formed by either dynamic processes such as contact between gas and liquid phases in a mass transfer operation or thermal processes such as condensation. Sulzer mist eliminators provide an effective solution to liquid entrainment problems in many types of equipment including scrubbing, absorption, stripping or distillation columns, evaporators, falling film condensers, knock-out vessels, three-phase separators, desalination plants, refrigeration plants, gas dehydration plants and compression systems. For best performance, it is important to achieve uniform gas flow distribution and maximum effective area. The most appropriate positioning is critical, in terms of disengagement distances from vessel inlet, outlet and other vessel internals.

For equipment based on direct and/or inertial interception, gas stream velocity affects all three principles involved in separation (impingement, coalescence and drainage). Flooding, or reentrainment of liquid, can occur if the flow of gas prevents drainage. The effective area of the mist eliminator is therefore established by determining an appropriate superficial velocity for the equipment using the well-known Souders Brown equation (1).

$$v = K \cdot \sqrt{\frac{\rho_l - \rho_v}{\rho_v}} \quad \text{.....(1)}$$

v = maximum superficial gas velocity
ρ_l = liquid density
ρ_v = gas density
K = a constant which is specific to the selected type of separation equipment

Derating factors are often applied to allow a safety margin for exceptional conditions such as liquid slugs and gas surges, and the K-value must be optimised to suit specific process conditions, and challenging physical properties such as low surface tension systems. The selection of K-value is therefore critical. A summary of the relative performance characteristics for mist elimination is listed in Table 1.

Sulzer KnitMesh™
Wire Mesh Mist Eliminators

Sulzer KnitMesh mist eliminators have an excellent track record as a low cost, highly versatile and efficient method of removing liquid entrainment from gas streams. They are produced as a bed of knitted mesh, which presents a tortuous path and large surface area to the droplets entrained in the gas stream. Separation is achieved by impingement on, and capture by, the filaments of the mesh where the droplets coalesce and drain (Figure 1). Installation can be made in a variety of ways but gas flow is usually either vertically upwards, with the liquid draining counter current to gas flow, or horizontal, with the liquid draining in a direction perpendicular to the gas flow. They provide excellent separation efficiency down

	Vane packs – simple vanes	Vane packs – with drainage channels	Axial cyclones	Knitted mesh mist eliminators
Gas handling capacity	High	High	Very high	Moderate
Turndown capacity	30% - 50%	30% - 50%	30% Higher with preconditioner	25%
Efficiency	High down to approx. 25 µm	High down to approx. 25 µm	High down to approx. 10 µm	Very high down to 2-5 µm
Liquid load capacity	Moderate	High	High	Moderate
Solids handling capability	Moderate	Low	Moderate-high	Low
Liquid viscosity	Suitable for high viscosities/ waxes	Prone to fouling with high liquid viscosities/ waxes	Suitable for high viscosities/ waxes	Prone to fouling with high liquid viscosities/ waxes
Pressure drop	Low	Low	Moderate	Low

Table 1: Summary of relative performance characteristics for mist elimination

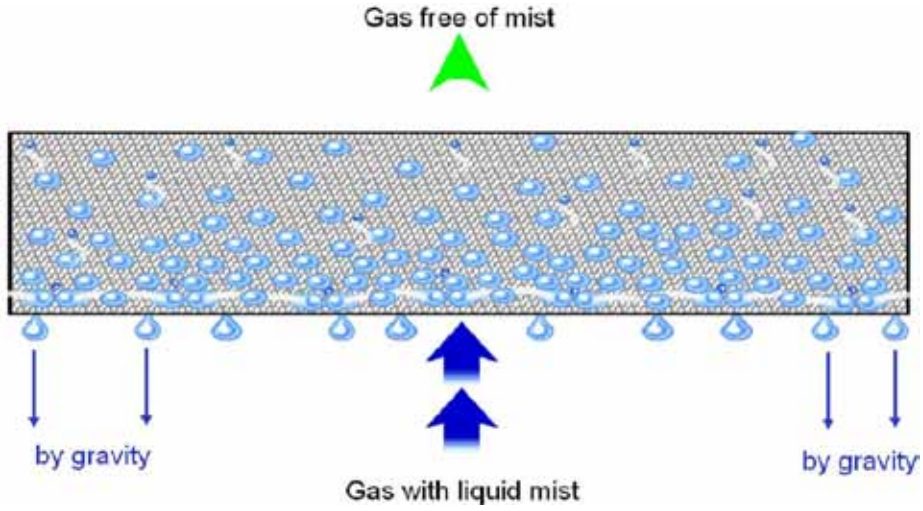

Figure 1: Gas-liquid separation using Sulzer KnitMesh Wiremesh Mist Eliminator

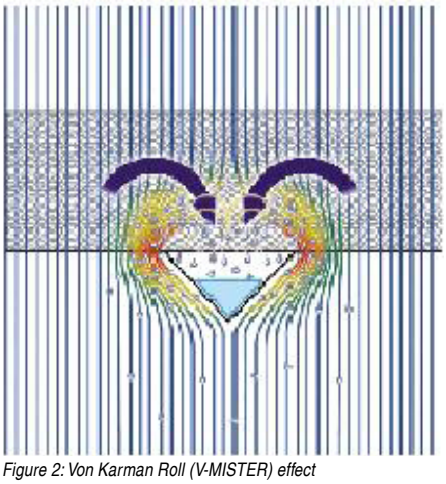

Figure 2: Von Karman Roll (V-MISTER) effect

to droplet sizes as small as 2 µm, and with a pressure drop typically less than 2.5 m bar.

Sulzer KnitMesh V-MISTER™

The Sulzer V-MISTER provides high performance wherever liquid entrainment must be removed from a vertically flowing gas stream. Mist eliminators with Sulzer V-MISTER technology employ the mechanism of a von Karman Roll around a bluff body (Figure 2) to obtain high vapour and liquid handling capacity. A vortex develops in a low-pressure zone down-stream of the channel that has been attached to the bottom of the mesh pad. Collected droplets deposit in the trough and form a flowing liquid stream there. The high capacity channels of the V-MISTER shield the collected liquid and then drain it in steady streams from two sides of the mist eliminator at the column wall, where

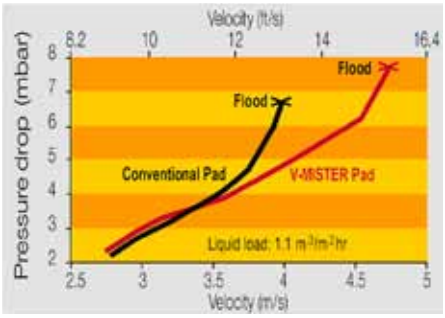

Figure 3: Higher capacity with Sulzer KnitMesh V-MISTER

gas velocity is so low that re-entrainment is limited. This simple enhancement to a standard mesh pad improves mist elimination because the higher velocities increase the droplets' inertial impaction with the wires or filaments. In addition, the strategically placed collecting channels provide higher operational gas and liquid flow capacity (Figure 3).

Sulzer Mellachevron™ Mist Eliminator

Sulzer Mellachevron vane mist eliminators are high capacity inertial separators constructed as banks of parallel, chevron profiles, which cause the gas to change direction several times from inlet to outlet. Momentum forces entrained liquid droplets to impinge on the vane surfaces where they form a liquid film and drain. The Sulzer Mellachevron range is divided into a number of categories depending on direction of gas flow and the complexity of the vane profile.

Simple Sulzer Mellachevron profiles separate liquid by impingement, coalescence and drainage on the vane surface with no disengagement of the liquid from the gas stream. They are particularly suitable for applications with a significant risk of fouling due to solid particles or high viscosity liquids in the feed but have relatively low gas handling capacity. More sophisticated designs provide special separation channels to allow disengagement of liquid and drainage from the vane surface. This increases the capacity of the separator and gas load factors of up to 0.45 m/s are possible. This makes them an excellent choice when equipment size is critical, for example, in offshore applications or for de-bottlenecking existing equipment.

Combined Systems

Increasing gas capacities and higher performance requirements in mass transfer equipment are challenging the capabilities of conventional mist eliminator equipment.

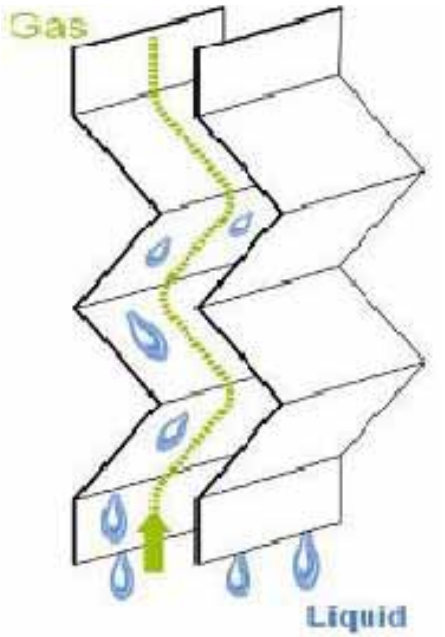

Figure 4: Gas-liquid separation using Sulzer Mellachevron Mist Eliminator

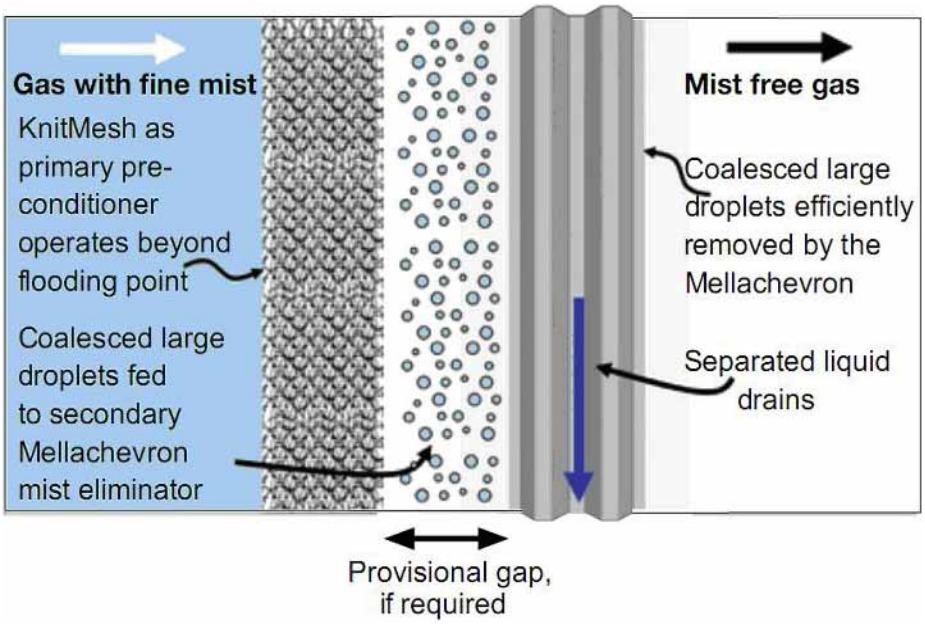

Figure 5: Combining different technologies to enhance performance

To solve this, Sulzer Chemtech offers combined systems, which optimise the benefits of individual types of equipment and improve overall performance. For example (Figure 5), KnitMesh mist eliminators can be used in combination with Sulzer Mellachevron vane packs or Shell Swirltubes to produce very high separation efficiencies at high gas loadings. By using the KnitMesh mist eliminator as a pre-conditioner for the Mellachevron, it is operated above its normal entrainment or flooding point and consequently liquid is stripped away from the downstream surface. The liquid dispersion reentrained from the mesh mist eliminator has a larger mean diametre and is suitable for subsequent separation by secondary, high capacity equipment. Additional benefits of combined systems include: the ability to design the equipment to provide very high turndown capabilities because at low gas velocities, where high capacity separators tend to be ineffective, the KnitMesh preconditioners behave as conventional mist eliminators.

Sulzer MKS Multi Cassette™

The Sulzer MKS Multi Cassette separator was designed to provide higher droplet removal efficiency and capacity with lower costs. The MKS consists of an axial inlet cyclone with a succession of separating cassettes mounted above it. The inlet cyclone swirls the gas, thereby causing some of the droplets to be separated initially. This liquid is collected in the bottom cassette and drained. Above the cyclone, the gas, still carrying the remaining entrained droplets, is distributed radially outward to the cassettes. Each cassette is equipped with several layers of wire mesh packing which efficiently separates the remaining droplets by both direct interception (barrier effect) and inertial interception. The liquid collected in each cassette is drained to the next lower cassette by a piping system. Finally, all the liquid is collected at the bottom cassette and then drained downwards out of the device through pipes.

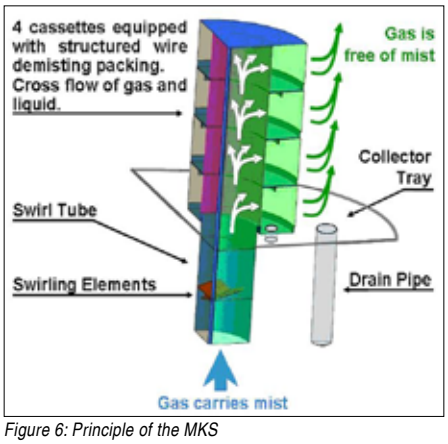

Figure 6: Principle of the MKS

MKS - Application in Gas Drying Column (Glycol Contractor)

The drying of natural gas in glycol (often TEG) dehydrators is a widely used and well-established process. However, the use of modern, high-capacity packing such as Sulzer MellapakPlus™ in absorption columns has increased the demands on ancillary equipment as well. In these applications, the droplet size is in the range of 5–25µm. To minimise the carryover, a glycol mist eliminator is required at the top of the column in order to satisfy the stipulated standard of no more than 13.7 litres loss of glycol per million standard cubic metres of gas (0.1 USgal/MMSCF). This loss expressly concerns only the glycol present in liquid form. As a result, a column equipped with high performance packing requires a suitably sized high capacity mist eliminator to meet design gas flow rates. The MKS Multi Cassette mist eliminator ideally combines with Sulzer MellapakPlus in glycol dehydrators to provide proven performance in natural gas drying columns.

MSK - Application in Separators

The separation of hydrocarbon liquids from natural gas under high process pressure is always a challenge for mist eliminators. Until now, designs for high-capacity separators required axial cyclone or vane pack mist eliminators. However, vane pack mist eliminators are

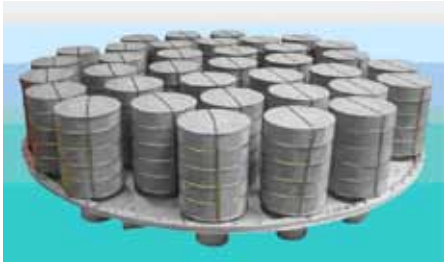

Figure 7: Sulzer MKS Multi Cassette

generally not recommended for high-pressure applications containing hydrocarbon liquids and tend to have relatively low separation efficiency. Axial cyclones are often the first choice and are optimally designed for these tough conditions, but they also require a higher minimum available installation height in the separator. When converting separators to higher capacity, the available installation height is often limited. Also, modifications inside the column can be restricted because, in general, no additional attachments can be welded directly to the column wall. With the MKS Multi Cassette mist eliminator, Sulzer provides an optimal addition to the category of high-capacity mist eliminator internals.

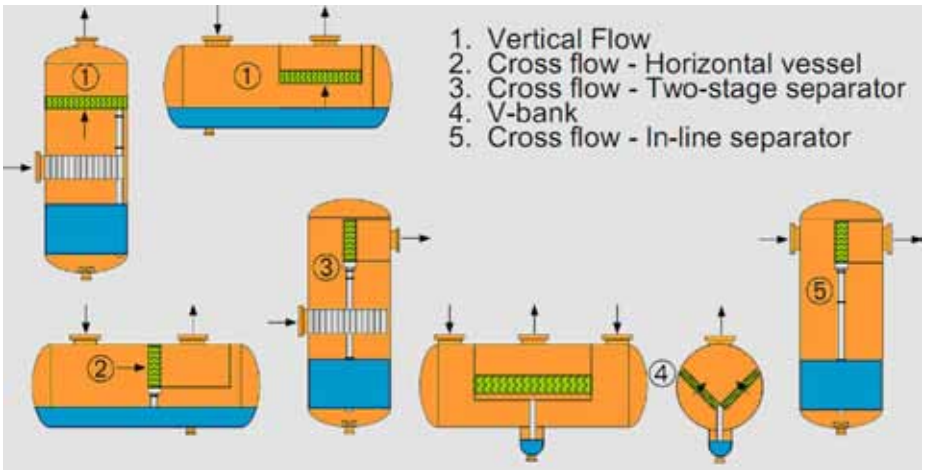

Figure 9: Various vessel arrangements

Shell Swirltube™

Axial flow cyclonic mist eliminators have been widely adopted in hydrocarbon systems where high capacity is important. They are often used in high-pressure applications where the performance of vane packs tends to deteriorate and where mesh mist eliminators are also undesirable because of their limited capacity and therefore large vessel sizes. The Shell Swirltube (Figure 8) is, in essence, a stainless steel tube with a swirler at the inlet and longitudinal slits in the tube wall. Liquid is separated by impaction of droplets and on the tube wall by the centrifugal forces induced by the swirling gas flow.

Re-entrainment of this liquid is prevented by draining the film via the slits to the liquid collection chamber outside the tube. To ensure the proper functioning of the Swirltube, it is essential that some gas is also bled through these slits. This gas leaves the liquid collection chamber via the secondary outlets at the top of the Swirldeck assembly. Performance can be improved by using a secondary KnitMesh mist eliminator to separate entrainment from the gas leaving the secondary outlets. The main fraction of the gas leaves the Swirltube via the primary gas outlet at the top. Drain pipes guide the liquid, collected in the space between the tubes and on the upper cover of the Swirldeck, to below the liquid level.

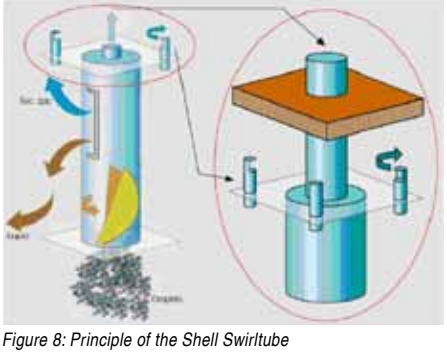

Figure 8: Principle of the Shell Swirltube

Scaling-up of a separator equipped with a Swirldeck is done simply by increasing number of Swirltubes proportional to the gas flow in the separator.

Selection of separation technologies is function of the dispersed liquid phase concentration, droplet size and the required separation efficiency. Their typical application window is for separation of liquid/gas or three-phase liquid/liquid/gas mixtures.

Shell High Capacity Separators

Shell proprietary high-capacity gas/liquid separators, such as Shell SVS™, SMS™, SMSM™ and SMMSM™ separators, combine the best features of the separation products from Sulzer Chemtech portfolio. Shell gas/liquid separators combine Schoepentoeter, KnitMesh and Swirldeck separation technologies in a single vertical vessel drum.

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When a high capacity and high separation efficiency is required, SMS (M) technology is the lowest weight and volume solution for phase separation offshore and onshore. It gives up to 2.5 times more capacity compared to a conventional KnitMesh mist eliminator without vessel replacement. Shell SMS, SMSM and SMMSM gas/liquid separators (Figure 7) are named after the configuration of the different internals used for each type of separator:

- Schoepentoeter or Schoepentoeter Plus (S) - used as feed inlet device for vapour distribution with bulk liquid removal
- KnitMesh (M) - which acts as coalescer and separator, depending on the gas flow rate
- Double Primary KnitMesh (MM) - specially developed for applications with two immiscible liquid phases in the feed to the separators (such as glycol/ condensate in Dew-Point Separators)
- Swirldeck (S) - comprising multiple Swirltubes.
- A second KnitMesh (M) is used downstream of the Swirldeck in SMSM gas/liquid separators for demisting secondary gas. In fouling or waxy service, the KnitMesh can be replaced by a Sulzer Mellachevron vane pack (SVS systems). ■

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