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## LIST OF TABLES



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# INTRODUCTION

## Scope

Mist elimination, or the removal of entrained liquid droplets from a vapor stream, is one of the most commonly encountered processes regardless of unit operation. Unfortunately, mist eliminators are often considered commodity items and are specified without attention to available technologies and design approaches. The engineered mist eliminator may reduce liquid carryover by a factor of one hundred or more relative to a standard unit, drop head losses by 50% or more, or increase capacity by factors of three or four. This manual summarizes cost effective approaches to reducing solvent losses or emissions, extending equipment life and maintenance cycles using proven and cost effective technologies and techniques.

In the chemical process industry, there are a number of processes where gases and liquids come into contact with each other and whenever this happens the gas will entrain some amount of liquid particles. This liquid phase which gets carried away into the gaseous phase can lead to a number of problems like loss of product, equipment damage, process inefficiency etc. and needs to be eliminated.

Mist elimination can be defined as the mechanical separation of liquids from gases. The equipment used for the removal of this entrainment is referred to as a mist eliminator or demister.

KLM Technology Group would be happy to assist in your needs for demister pads. We can engineer, supply or troubleshoot your application. Please contact us at info@klmtechgroup.com.

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## General Design Consideration

## Mist Eliminators

Wire mesh mist eliminator, in the most general sense, is a simple porous blanket of metal or plastic wire retains liquid droplets entrained by the gas phase. The separation process in the wire mesh mist eliminator includes three steps: the first, being `inertia impaction' of the liquid droplets on the surface of wire. As the gas phase flows past the surface or around wires in the mesh pad the streamlines are detected, but the kinetic energy of the liquid droplets associated with the gas stream may be too high to follow the streamline of the gas and they impinged on the wires.

The second stage in the separation process, is the coalescence of the droplets impinging on the surface of the wires. In the third step, droplets detach from the pad. In the vertical flow installations, the captured liquid drains back in the form of large droplets that drip from the upstream face of the wire mesh pad. In the horizontal flow systems, collected liquid droplets drain down through the vertical axis of the mesh pad in a cross flow fashion.

There are a number of industrial processes where in the liquid and the gas phases come into intimate direct contact with each other as a part of the process. As a result of viscous and aerodynamic forces, liquid droplets of various sizes are entrained and carried along with the moving gas stream. In most instances, it is desirable or even mandatory that these droplets be removed from the gas stream for different reasons.

Examples of such considerations are recovery of valuable products, improving emission control, protection of downstream equipment, and improving product purity. A typical use of mist eliminator takes place in such operations as distillation or fractionation, gas scrubbing, evaporative cooling, evaporation and boiling, trickle equipment for sewage and the like.

There are several devices which are offered to industry for separating the entrained liquid droplets and each of which are effective over their own particular range of mist size. Mist eliminators can be summarized into the following groups settling tanks, fiber filtering candles, electrostatic precipitators, cyclones, impingement van separators, and wire mesh.

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In the early days of evaporators, especially in thermal desalination plants, the solid vane type separators were used. However, the system suffers from the following drawbacks:

1. high pressure drop (which could result in the total loss of temperature driving force between stages)
2. excessive brine carry over.

Today, the wire mesh mist eliminator is widely used in thermal desalination plants to remove the water droplets, which may be entrained with the boiled or and washed off vapor. This water droplet must be removed before the vapor condensation over the condenser tubes. If the mist eliminator does not separate efficiently the entrained water droplets, it will cause the reduction of distilled water quality and the formation of scale on the outer surface of the condenser tube. The last effect is very harmful because it reduces the heat transfer coefficient and enhances the corrosion of the tube material.

The main features of wire mesh mist eliminators are low pressure drop, high separation efficiency, reason-able capital cost, minimum tendency for flooding, high capacity, and small size. The performance of wire mesh eliminators depends on many design variables such as supporting grids, vapor velocity, wire diameter, packing density, pad thickness, and material of construction. Because the wire-mesh is not rigid, it must be supported on suitable grids.

To obtain minimum pressure drop, maximum throughput, and maximum efficiency, the support grids must have a high percentage of free passage. To take full advantage of the 98% or so free volume in the wire-mesh, the free passage through the support grids should be greater than 90%. If the free passage through the support grids is much below 90%, the accumulated liquid is prevented from draining back through the support grids, causing premature flooding.

Typically, maximum allowable velocity for a mist eliminator is limited by the ability of the collected liquid to drain from the unit. In vertical up flow mesh demister, when the gas velocity increases past design levels, liquid begins to accumulate in the bottom of the unit. The liquid buildup results in re-entrain of the downstream. This is because the inertia of the incoming gas prevents the liquid from draining out of the unit. In horizontal units, the gas inertia pushes the captured liquid toward the downstream face.

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As a rule, smaller diameter wire targets collect smaller liquid droplets more efficiently. For example, a 10 mm wire removes smaller droplets than a 200 mm wire. However, a bed of 10 mm wires normally has the tendency to flood and re-entrain at much lower gas velocities than a bed of 200 mm wire. This is because the thinner wires provide dense packing that can trap the liquid by capillary action between the wires.

Interweaving of small diameter wires with larger diameter wire has been used often to tackle some of the most difficult mist removal problems. This design uses the metallic or plastic wires as a support structure to hold the one wires apart. Even with this approach, the throughput capacity of the unit is limited, compared to that possible with conventional mesh. Special internal mesh geometry modifications are now available that allow these bi-component (that is, small fiber and large-diameter wire mesh) configurations to operate at velocities essentially the same as conventional mesh designs.

These ultra-high-efficiency designs can be substituted for conventional mesh and used, for example, in the dehydration towers of natural gas production plants, where even small losses of absorption chemicals, such as ethylene glycol, can be a significant operating expense.

Construction materials for the wires include metal, fiberglass, plastics or polymers such as polypropylene or Teflon. Recently, three new alloys have been made available in wire form, which routinely provide three to five times the service lives of the traditional materials. These are Lewmet 66, SX and Saramet. They can offer improved service depending on the temperature and acid concentration of the gas stream. The gas phase velocity should be limited to 4 ± 5 m/s to prevent any re-entrain of the water droplets captured in the wire mesh pad

The capacity of a wire mesh mist eliminator is determined by the conditions of loading and flooding. Beyond the loading point, the liquid holdup is high enough to improve the separation efficiency. The demister should operate at a velocity higher than the loading velocity. Flooding occurs when the vapor velocity exceeds a critical value. To prevent flooding, the mist eliminator must be designed and sized so that the design velocity is below the critical flooding velocity.

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Wire mesh pad mist eliminators consists of a pad of knitted metal or plastic wire mesh usually sandwiched between grids for mechanical support. Units above 600 mm diameter are normally split into sections in the range of 300 to 400 mm to facilitate installation through a normal vessel manway. The pads are cut slightly oversized to ensure a snug fit and eliminate possibility of a vapor bypass either between sections or between pad and vessel wall. Each mesh pad is formed from crumpled layers of fabric knitted form a monofilament with the direction of crimp rotated 900 in each adjacent layer to provide a uniform void age with a high ratio of filament surface.

Mesh pad mist eliminators can be installed for either vertical or horizontal vapor flow. The mesh pads are generally 100- 150 mm thick for vertical vapor flow and 150-200 mm for horizontal vapor flow. Where mesh pad thickness exceeds 300 mm, the unit is usually divided into 2 separate layers so that the section will pass through normal vessel manways and in these cases wire screens are fitted between layers to maintain pad integrity during installation.

Mesh demisters consist of a pad of knitted metal or plastic wire mesh usually sandwiched between grids for mechanical support. Except for units less than about 600mm diameter, they are normally split into sections of between 300 to 400mm wide to facilitate installation through a normal vessel manway. The pads are cut slightly oversize to ensure a snug fit and thus eliminate any possible vapor by-pass either between sections or between pad and vessel wall (or shroud). Each mesh pad is formed from crimped layers of fabric knitted from monofilament with the direction of the crimp rotated 90 degrees in each adjacent layer to provide a uniform void age together with a high ratio of filament surface per unit volume of pad.

Standard support grids consist of a framework of 25mm x 3mm thick flat bar fixed to a grid consisting of 6mm rods usually spaced on 150mm centers to retain the mesh with minimum obstruction of the face of the pad. The top and bottom grids are connected by spacer rods passing through the mesh that are welded to each grid to ensure the dimensional stability of the pad. Mesh pads can also be furnished with special heavy duty support grids where these are required to provide a working platform inside the vessel.

Mesh pads can be installed either horizontally for vertical vapor flow or vertically for horizontal vapor flow. For vertical vapor flow, mesh pads are normally either 100mm or 150mm thick and for horizontal flow are normally greater at 150 to 200mm+ thick. W

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here mesh pad thickness exceeds 300mm, the unit is usually divided into 2 separate layers so that the sections will pass through normal vessel manways and in such cases wire screens are fitted between layers to maintain pad integrity during installation.

**Specification**

Mesh mist eliminators are manufactured in a wide variety of metals and synthetics of which the following are supplied as standard:

a. Stainless steels (types 304, 304L, 316, 316L, 321, 430)
b. Monel
c. Nickel & nickel alloys
d. Copper & copper alloys
e. Glass wool or fiber
f. Polypropylene
g. Halar / PTFE

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**Mist eliminator applications**

Oil and Gas Industry

Separating liquids & contaminants from the oil is a fundamental requirement to the oil & gas industry. Mist eliminators are used to remove carry over liquids, removal of condensed liquids and removal of contaminants etc.

Process Industry

Mist elimination plays a vital role in recovering lost product and in protecting downstream equipment's and processes. They provide predictable operation even under heavy liquid loading. Appropriately designed mist eliminators allow process to run at velocities facilitating small apparatus dimensions.

Flue Gas Desulphurization

Appropriate use of mist eliminators in this application protects the environment by preventing droplets escaping into the atmosphere. It captures the liquid solvent, thus minimizing cost of cleaning gases. It cleans the exhaust gas phase from droplets thus protecting the downstream heat exchangers.

Sulphur Acid Plants

Well-designed mist eliminators play a significant role in cost effective operation of sulphuric acid plants. If mist eliminators are not designed properly it may lead to corrosion of blowers, heat exchangers and vessels adversely affecting plant efficiency.

Mist Eliminator Benefit

a. Improves throughput capacity
b. Improves product purity
c. Provides equipment protection
d. Low pressure drop
e. Provides environmental protection

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Mist Eliminators Selection Guide

Mist eliminators find a wide variety of applications such as evaporators, three phase separators, knockout vessels, scrubbers etc. The choice of mist eliminator must be done on the basis of the application requirements. Products are available in a wide array of metals, plastics, thermoplastics to suit a variety of applications.

1. Mesh Pad Mist Eliminator

   The mesh pad mist eliminator removes droplets by impingement on surface of a wire. The liquid collected on the filament is drained off under gravity. These mist eliminators provide almost complete removal of droplets down to 3 to 5 microns.

2. Plain Vane Pack Mist Eliminator

   The plain vane pack mist eliminator is a high efficiency mist eliminator commonly used for removing entrained liquids from vapor flowing vertically upwards. These mist eliminators use corrugated vanes as a mechanism for mist elimination.

3. Pocketed Vane Pack Mist Eliminator

   The high capacity vane pack mist eliminators use a hooked vane mechanism for higher capacity mist elimination. They provide for efficient droplet removal and superior resistance to fouling for high rate horizontal vapor flow.

4. Mist Eliminators for high efficiency mist elimination

   The high efficiency mesh pad mist eliminators remove droplets by impingement on the wire surface. The liquid collected on the filaments drains off under gravity. They provide almost complete removal of droplets down to about 3-5 microns. They provide a turndown range of vapor rate of around 3:1.

At excessively high velocity the liquid droplets that impinge on the wire surface are sheared off by the vapor and entrained before they are able to drain. At very low vapor velocities all but the larger droplets are able to follow the vapor path through the mesh and thus avoid impingement. However, the inherent design of the separator vessel means that in most applications an effective turndown of 10:1 can be achieved.

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High efficiency mesh pad mist eliminators can provide liquid entrainment solutions in a variety of equipment's including

a. Scrubbers & distillation columns
   3 phase separators
b. Knock out vessels
   Evaporators
c. Falling film condensers
   Desalination plants
d. Steam drum
   Gas dehydration plants

**Advantages of Demister**

Demister is a necessity to be used where liquid in gaseous or vapor stream is not acceptable. For example – compressor suction lines. Separation of mist from gaseous or vapor stream can improve the operating condition, optimize process indicators, reduce corrosion of the equipment, extend equipment life, increase the amount of processing and recovery of valuable materials, protect the environment, and decrease air pollution. Demister also produces high quality condensate suitable for use a boiler's feed water.

Must have Features in a Demister

- Simple structure.
- Lightweight.
- High porosity.
- Cause less pressure drops.
- Large surface area.
- High mist separating efficiency.
- Easy to install, operate and maintain.
- Easily tailor made to suit most vessel shapes and sizes.
- Durable and long service life.
- Corrosion resistance.

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## DEFINITIONS

**Air standard** - Air having a temperature of (20°C), a relative humidity of 36 percent, and under a pressure of 14.70 PSIA. The gas industry usually considers (16°C) as the temperature of standard air.

**Annular velocity** - the actual flow rate divided by the annulus area. Modeled as a linear function with vertical distance, and the annular velocity is zero at the bottom of the cartridge and increases to a maximum value at the top of the cartridge.

**Annulus** - A ring-like part or, the orifice of a hollow die, through which extruded metal flows from the press.

**Coalescence** - Liquid particles in suspension that unite to create particles of a greater volume.

**Coalescer-** A mechanical process vessel with wet table, high-surface area packing on which liquid droplets consolidate for gravity separation from a second phase (for example gas or immiscible liquid).

**Control Volume-** A certain liquid volume necessary for control purposes and for maintaining the velocity limit requirement for degassing and to counter foam in separators.

**Conventional Gas-Liquid Separator-** Vertical or horizontal separators in which gas and liquid are separated by means of gravity settling with or without a mist eliminating device.

**Critical Diameter-** Diameter of particles larger than which will be eliminated in a sedimentation centrifuge.

**Density** - The density of a homogeneous substance is the ratio of its mass to its volume. The density varies as the temperature changes and it is usually expressed as the mass per unit volume at a specified temperature.

> **Absolute Density** – The mass of a substance per unit volume at a specified temperature.

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**Relative Density** - The ratio of the mass of a given volume of fluid to the mass of an equal volume of pure water at the same temperature and pressure. Relative density replaces the term “specific gravity”.

**Relative Density At 60°** - Fluid relative density measured against water with both materials at 60 degrees F and reference pressure of 14.696 psia (or equilibrium pressure). Equivalent to “RD 60/60”

**Demister Mist Extractor-** A device installed in the top of scrubbers, separators, tray or packed vessels, etc. to remove liquid droplets entrained in a flowing gas stream.

**Design Pressure -** The pressure used in the design of a vessel component for the most severe condition of coincident pressure and temperature expected in normal operation

**Disengaging Height-** The height provided between bottom of the wire-mesh pad and liquid level of a vapor-liquid separator.

**Entrainment** - A process in which the liquid boils so violently that suspended droplets of liquid are carried in the escaping vapor.

**Fabric Filter-** Commonly termed "bag filters" or "baghouses", are collectors in which dust is removed from the gas stream by passing the dust-laden gas through a fabric of some type.

**Filter-** A piece of unit operation equipment by which filtration is performed.

**Filter Medium-** The "filter medium" or "septum" is the barrier that lets the liquid pass while retaining most of the solids; it may be a screen, cloth, paper, or bed of solids.

**Filtrate-** The liquid that passes through the filter medium is called the filtrate.

**Gas-Liquid Separator -** vertical or horizontal separators in which gas and liquid are separated by means of gravity settling with or without a mist eliminating device

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**Highspeed mist eliminator –** separator removal of very small droplets can be achieved using a two stage mist eliminator by fitting a mesh pad to the upstream face of the unit to coalesce droplets as small as 4 to 5 microns into droplets in the size range which are easily removed by the vane separator

**Hold-Up Time-** A time period during which the amount of liquid separated in a gas-liquid separator is actually in the vessel for the purpose of control or vapor separation.

**Knock-Out-** A separator used for a bulk separation of gas and liquid.

**Line Drip-** A device typically used in pipelines with very high gas-to-liquid ratios to remove only free liquid from a gas stream, and not necessarily all the liquid.

**Mesh-** The "mesh count" (usually called "mesh"), is effectively the number of openings of a woven wire filter per 25 mm, measured linearly from the center of one wire to another 25 mm from it.

**Mist Cyclone Eliminator** - separator multi-cyclone elements are designed specifically for the removal of high levels of liquids and solids from gas in a single separation stage.

**Nozzle -** A short flanged or welded neck connection on a drum or shell for the outlet or inlet of fluids; also, a projecting spout for the outlet or inlet of fluids; also a projecting spout through which is fluid flows.

**Operating Pressure -** The pressure at the top of the vessel at which it normally operates. It shall be lower than the MAWP, design pressure, or the set pressure of any pressure relieving device.

**Operating Temperature -** The temperature that will be maintained in the metal of the part of the vessel being considered for the specified operation of the vessel

**Open Area-** A percentage of the whole area of a woven wire filter.

**Overflow-** The stream being discharged out of the top of a hydrocyclone, through a protruding pipe, is called "overflow". This stream consists of bulk of feed liquid together with the very fine solids.

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**Pressure drop** - the difference in total pressure between two points of a fluid carrying network. A pressure drop occurs when frictional forces, caused by the resistance to flow, act on a fluid as it flows through the tube.

**Separator** - a cylindrical or spherical vessel used to isolate the components in mixed streams of fluids.

**Settling velocity -** The velocity reached by a particle as it falls through a fluid, dependent on its size and shape, and the difference between its specific gravity and that of the settling medium; used to sort particles by grain size.

**Stokes' law** - the law that the force that retards a sphere moving through a viscous fluid is directly proportional to the velocity of the sphere, the radius of the sphere, and the viscosity of the fluid

**Surge tanks-** These are storage tanks between units and can serve a variety of purposes. They can dampen fluctuations in flow rate, composition or temperature. They can allow one unit to be shut down for maintenance without shutting down the entire plant.

**Schoepentoeters** - inlet devices are used in phase separator vessels as well as stripper, absorber, distillation columns etc. mainly for even distribution of the inlet flow across the vessel or column cross sections. Even distribution of the fluids across the cross section geometries becomes important in order to minimize the channeling of these fluids, which can lead to reduced equipment efficiency.

**Target Efficiency-** The fraction of particles or droplets in the entraining fluid of a separator, moving past an object in the fluid, which impinge on the object.

**Terminal Velocity or Drop-Out Velocity-** The velocity at which a particle or droplet will fall under the action of gravity, when drag force just balances gravitational force and the particle (or droplet) continues to fall at constant velocity.

**Underflow-** The stream containing the remaining liquid and the coarser solids, which is discharged through a circular opening at the apex of the core of a hydrocyclone is referred to as "underflow".

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**Vessel height** - the distance from the bottom of the flange to the inside bottom of the dissolution vessel.

**Vapor Space-** The volume of a vapor liquid separator above the liquid level.

**Vane mist eliminators** – vessel consist of a series of plates or vanes spaced to provide passage for vapor flow and profiled with angles to provide sufficient change of direction for liquid droplets to impact, coalesce and drain from the surfaces of the plates

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## NOMENCLATURE

| | |
|---|---|
| $M_L$ | Flow rate liquid kg/h |
| $M_V$ | Flow rate vapor kg/h |
| P | Operating Pressure atm |
| $\eta_L$ | Dynamic viscosity Pa.s |
| d | Nozzle diameter m |
| $t_{wm}$ | Thickness of demister mat m |
| H/D | Height diameter ratio |
| $f_\eta$ | Derating factor |
| $Q_{max}$ | Volumetric flow rate m³/s |
| $A_G$, | min Minimum required vessel cross-sectional area for gas flow m² |
| D | Diameter m |
| h | height of vessel required for liquid hold-up m |
| H | Vessel height m |
| $Q_L$ | Liquid flow volumetric m³/s |
| $Q_G$ | Gas flow volumetric m³/s |
| $v_m$ | Mixing velocity m/s |
| $v_G$ | Gas velocity m/s |
| $\Delta P_{wm}$ | The pressure drop across the mistmat Pa |
| $\Delta P$ | The pressure differential Pa |
| LZA (HH) | Height of vessel required for liquid hold-up m |
| L | Length m |

### Greek Letters

| | |
|---|---|
| $\rho_m$ | Mixing density kg/m$^3$ |
| $\phi_{feed}$ | Feed flow parameter |
| $\phi_{wm}$ | Function of the flow parameter of the feed |
| $\lambda_{max}$ | Maximum gas load factor m/s |
| $\rho_L$ | Liquid density kg/m$^3$ |
| $\rho_V$ | Vapor density kg/m$^3$ |

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