OMEGA SEPARATIONS

MIST ELIMINATION

COMPANY BROCHURE

CONTENTS

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INTRODUCTION TO OMEGA SEPARATIONS

Omega Separations is one of the few companies worldwide only focusing on gas-liquid and liquid-liquid separation technology. With our team of highly experienced separation specialists we are able to offer the best solution for existing problems or an affordable and competitive replacement of existing equipment.

Omega separations is a global company with sales offices in Singapore for the Asia-Pacific region, Belgium for the European region and Dubai for the Middle East and Africa.

Additionally, we cooperate with local sales representatives in various countries around the globe. With this local presence we are able to respond to our Customers needs, and give a prompt Technical advice and fast delivery service.

Omega Separations' core business activities are:

Engineering Services

Tailored service packages as to suit specific requirements including:

- Feasibility studies
- Process and mechanical design
- Retrofitting existing equipment
- Optimization of performance

Supply of equipment

We can supply a wide range of gas-liquid and liquid-liquid separation equipment suitable for most application in the market.

Shut Down Delivery Service

Because of our local presence we can handle the shortest deadlines. This can be for unforeseen emergency situations requiring immediate assistance and urgent replacement or repair of separators; or for planned turnarounds where clients on beforehand decide not to take the mist eliminators on stock.

Site Supervision Service

Omega Separations can supply site supervisors having long years experience in doing installation and supervision jobs all around the world. They have the various certificates and can even assist installations on offshore platforms.

With the ever more complex retrofits and separation equipment that need to be installed we see more and more of our customers requiring these services to make sure the separation equipment is correctly installed and will perform in accordance with the designs and guarantees given.

Installation Training Centre

Omega Separations has a fully equipped training centre in Singapore where both end users and installation companies can come and learn how to effectively and correctly install separation equipment.

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GAS-LIQUID SEPARATION

Principles

Principle of mist formation

In all processes where gas and liquid are coming into contact, the gas will entrain liquid droplets. These entrained liquid droplets, called mist, can cause product loss, process inefficiencies and serious damage to critical equipments like turbines and compressors.

The liquid entrainment in these gas streams can either be formed by dynamic processes as in mass transfer operation, thermal processes such as condensation, or chemical reaction. Depending on the kind of process and the way the droplets are formed, they can have a very different size. It is therefore very important to understand the mechanism of this droplet formation in order to properly design the appropriate mist eliminator specific to the process.

Droplet formation can occur in various processes, for example:

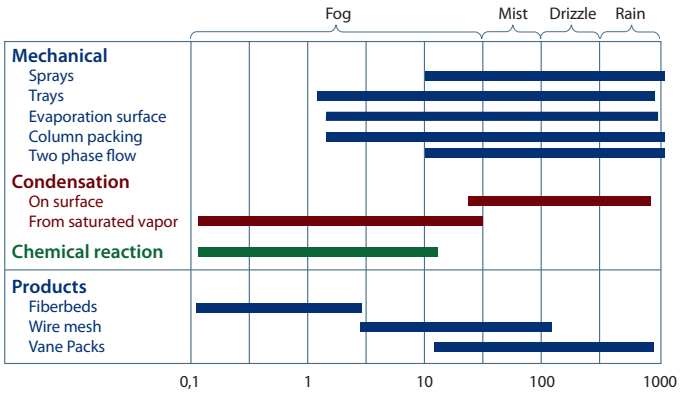
- Droplets can be formed when jetting occurs or bubbles burst in the gas/liquid interface in flooded packed bed scrubbers, distillation columns and evaporators.

- Where there is a high relative velocity between gas and liquid, droplets can be sheared from the wet surfaces. This type of problem is likely to occur in venturi scrubbers, two-phase flow in pipes and packings.

- Droplets can also be formed by thermodynamic changes in a system. For example, vapour condenses when saturated gases are cooled in condensers and heat exchangers, the gas can become supersaturated in places causing droplet formation. Similarly mists can result from gas phase reactions which yield a liquid product. Typical applications suffering from mist contamination include sulphuric, phosphoric and nitric acid plants.

- If the gas is travelling too fast to allow the liquid droplets to settle out under gravity, they become suspended (or entrained) in the gas or vapour. In most cases, the entrainment must be removed to purify the gas and prevent potential process or environmental contamination.

The below table gives an overview of the different sources of droplet formation and an indication on the respective range of droplet size, as well as an overview of the efficiency of the different types of mist eliminators.



Mist elimination systems provided by Omega Separations prove to be an effective solution to liquid entrainment problems in many types of equipment including:

- knock-out vessels
- 3-phase separators
- scrubbing, absorption, stripping or distillation columns
- evaporators
- falling film condensers
- desalination plants
- refrigeration plants
- gas dehydration plants
- compression systems

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Principle of mist capture

In order to select the correct type of equipment, we have to consider the various mechanisms of droplet capture, being;

- **Brownian Diffusion or Diffusional Deposition**
  This method is especially effective in the separation of very fine droplets or aerosols typically smaller than 2µm. At that size they are small enough to be affected by Brownian Motion. The main capture mechanism for submicron droplets in fiberbed mist eliminators is the seemingly random movement of microscopic particles suspended in the fluid (gas or liquid).

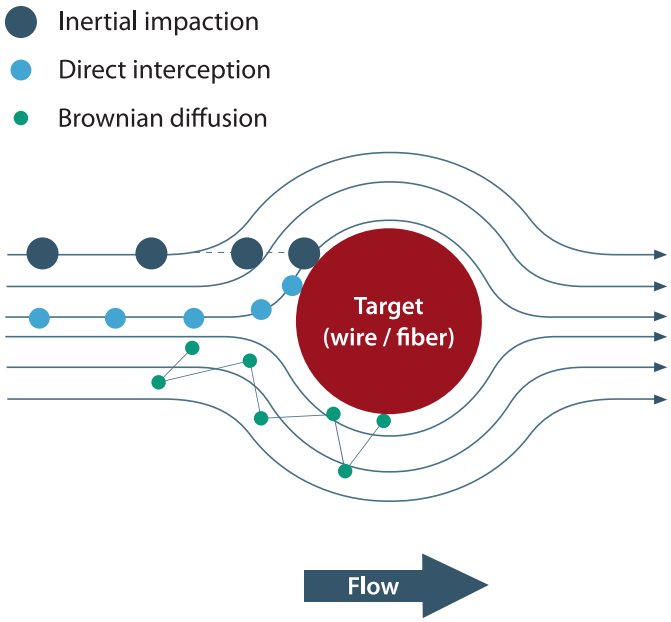
The Brownian motion of a particle in a fluid is thus due to the instantaneous imbalance in the combined forces exerted by collisions of the particle with the much smaller liquid molecules (which are in random thermal motion) surrounding it. This tiny motion can be enough to throw small droplets out of the gas streamlines and against fibers that they would otherwise flow around.

Since flow momentum is not involved here, the capture efficiency is not improved by the larger size of droplets, higher velocity, or higher relative liquid density. Instead the efficiency goes up with higher temperature, longer residence time in the fiber media, and closer packing of fibers, and efficiency will go down with greater droplet size and pressure.

- **Interception Capture or Direct Interception**
  This assumes that a droplet of a given diameter and negligible mass can follow the stream line around the 'target' wire or fiber. This mechanism occurs when the droplets that cannot be captured efficiently by inertial effects due to small size, low density, low velocity, etc. In that case they may nevertheless head so close to the target (a strand or a fibre) that they brush against the surface and adhere.

- **Inertial Interception or Inertial Impaction**
  This considers the droplet mass and predicts how momentum will make it deviate from the gas stream. As the gas changes direction, inertia or momentum keeps mist droplets moving in straighter paths and eventually they will adhere to the target wire or surface. There, they are held by surface forces and coalesce (merge) with other droplets, as soon as they are large enough they will disengage and be trickling down by gravitational settlement.

- **Gravitational Deposition**
  Works on the principle that large, slow moving droplets may separate from a gas stream under gravity. This is restricted to large droplet sizes and low superficial gas velocities which in that case makes the separator dimensions very large and totally uneconomical.



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Design advice

The below gives you an insight on the basics of separator design for impaction based mist eliminators and which factors should be taken into consideration.

However, the proper design of separation equipment involves more than just applying a few rules of thumb or equations. In order to ensure a good operation of separation equipment it is not sufficient to just calculate the velocity through it; the separator as a whole must be reviewed. Nozzle sizes, inlet devices, mutual distances between various components, etc will all contribute to the performance of the installed separation equipment. Based on our long standing experience in design and supply of separators, Omega Separations is able to tailor the mist eliminator design to suit virtually all applications.

Sizing of impaction based mist eliminators

For separation equipment based on Direct Impaction and Inertial Interception the gas velocity will affect all three principles involved in the separation of the liquid droplets, being the impingement, coalescence and drainage of the droplets. Flooding, or re-entrainment of liquid, can occur if the gas flow rate is too high and the flow of gas prevents drainage of the captured liquids.

The effective area of the mist eliminator is therefore established by determining an appropriate superficial velocity and thus size for the separator. The overall performance of the mist eliminator is then a balance between efficiency and pressure drop.

For good operation and the maximum operating flexibility it is generally recommended that the nominal/optimal operating velocity is established. This is a velocity at which there is a balance between the liquid droplets draining down from the separator and the liquid droplets entering and captured into the separator. At this point the capture efficiency is higher than at lower range velocities. However satisfactory performance can be guaranteed at velocities from about 30% to 110% of that value.

A certain formula, called the Souders-Brown equation is widely used in sizing a wire mesh or vane mist eliminator for a given throughput. It has long been the customary tool for predicting the maximum allowable vapour velocity in a trayed vapour-liquid contactor column.

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The version of the Souders-Brown equation commonly used for mist eliminators establishes a variable K called the vapour load factor—also known as the system load factor, Souders-Brown velocity, or K factor—as follows:

$$K = \frac{V_G}{\sqrt{\frac{(\rho_L - \rho_G)}{\rho_G}}}$$

K = vapour load factor (Souders-Brown velocity) in same units as V_G (m/s or ft/s)

V_G = gas velocity in same units as K (m/s or ft/s)

ρ_L = liquid density in same units as ρ_G (kg/m³ or lbs/ft³)

ρ_G = gas density in same units as ρ_L (kg/m³ or lbs/ft³)

The K factor can be considered an effective gas velocity for the purpose of expressing the throughput capacity limit, adjusted for the effects of liquid and gas density.

This parameter allows data gathered for a given mist eliminator and gas-liquid system—typically air and water—to be used in sizing mist eliminators of the same type for different gases and liquids.

In exceptional conditions such as liquid slugs or gas surge derating factors need to be applied to allow for a suitable safety margin. In several cases the K-value has to be optimized to suit specific process conditions and challenging physical properties such as low surface tension systems. The correct selection of K-value is critical and we therefore strongly recommend designs to be checked by our experienced engineering team.

PRODUCT PORTFOLIO

Wire Mesh Mist Eliminators

Construction Materials

- Stainless steels, duplex steel
- Alloy C276, 400, 625, 825, 20, etc...
- Plastics (PP, FEP, ETFE, ECTFE)
- Fibrous components (PTFE, Polyester, Glass fibres)

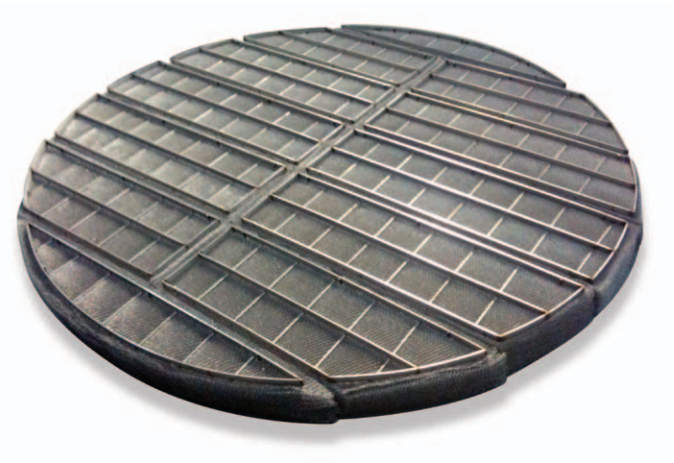
Typical Applications

There is a very large range of applications which are mainly in the following fields:

- Knock-out drums
- Evaporator systems
- Scrubbing systems and absorbers
- Glycol dehydration
- Gas processing
- Inert gas scrubbers
- Sulphuric acid drying towers
- Sulphur condensers
- Steam drums
- Inlet separators
- Turbo-expander suction drums
- Dew-point separators
- Compressor suction drums
- MSF/MED desalination

Characteristics

Wire Mesh Mist Eliminators are easy to install cost effective separators that are able to collect liquid particles 2 to 10 microns in diameter with essentially 100% efficiency if designed properly to the process conditions. They are available in almost any size or shape and can be manufactured in a broad range of metals or plastics.



They are produced as multiple layers of knitted mesh making it a dense pack and presenting a large surface area to the droplets entrained in the gas stream. The separation of the droplets is achieved by impingement on, and capture by, the wires of the mesh where the droplets coalesce and drain.

Most of the wire mesh mist eliminators are supplied complete with rigid open area support grids allowing direct installation onto support structures such as beams and rings. The mist eliminator is made out of sections allowing easy handling and access through the vessel man ways. Additional accessories such as tie wire, bolting, clamps and support beams can be delivered if needed.

Benefits

- **High collection efficiency**
- **Low installed cost**
- **Low pressure drop**
- **Fast delivery and service**

PRODUCT PORTFOLIO

Vane Pack Mist Eliminators

Construction Materials

- Stainless steels, Duplex Steels
- Alloy C276, 400, 625, 825, 20, etc...
- Thermal-set plastics, FRP

Typical Applications

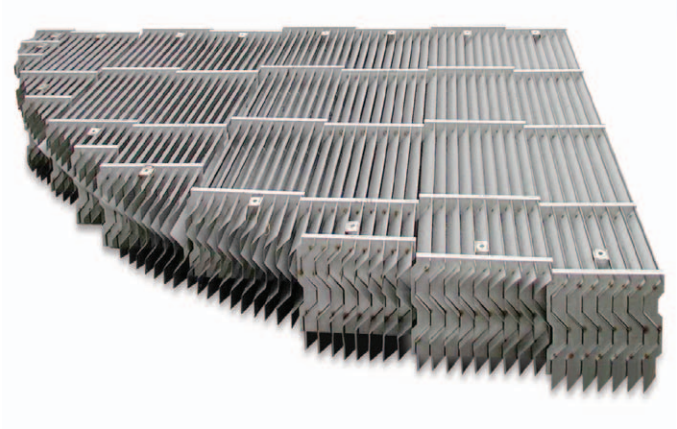
- Low Pressure Evaporators
- Refinery Vacuum towers
- Scrubbers in flue gas desulfurization (FGD) systems
- Pulp and Paper mills
- Sugar refinery

Characteristics

Vane Pack Mist Eliminators are high capacity separators; they collect essentially 100% of all particles greater than 8 to 40 microns in diameter, depending on design parameters. They are assembled as banks of parallel vane profiles. This design causes the gas to change direction a number of times from inlet to outlet of the separator. The intertia of the liquid droplets forces the entrained liquid droplets to impinge on the vane surfaces where they form a liquid film and drain. Simple Vane Pack profiles are particularly suitable for applications with a significant risk of fouling due to solid particles or high viscosity liquids in the feed.

Omega Separations offers a wide range of Vane Packs depending on the direction of gas flow and the complexity of the vane profiles.

Sectional installation of the vane banks allows installation and removal through the vessel manway.



Complex Vane Pack designs provide special separation channels to allow disengagement of liquid and drainage from the vane surface which increases the capacity. These profiles are therefore used when equipment size is critical, for example in de-bottlenecking of existing equipment.

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Benefits

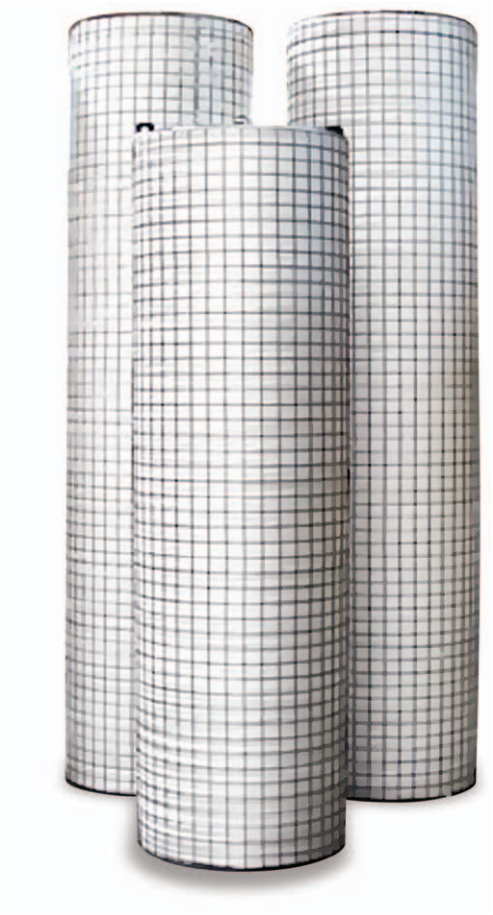
- **Suitable for applications where solids or sticky and viscous liquids are present and would plug a wire mesh mist eliminator**
- **Suitable for both vertical and horizontal gas flow**
- **Good collection efficiency in low pressure drop and vacuum applications**
- **Suitable for higher liquid and gas loads**

PRODUCT PORTFOLIO

Fiberbed Mist Eliminators

Construction Materials

Fiber bed mist eliminators are made out of dense layers of micron size fibers placed between two concentric cylindrical cages.



Various fibres can be used;

- chemical resistant glass fibres
- polyester
- carbon fibres

The cages are available in:

- Stainless steel
- Carbon steel
- Special alloys
- FRP
- PVDF
- PTFE
- Polypropylene

Typical Applications

- Metallurgical acid plants
- Spent acid plants
- Ammonia scrubbing
- Ammonium nitrate
- Lube oil vent from compressors
- Digesting of wood pulp
- Chlorine Industry

Characteristics

Fiberbed Mist Eliminators are high efficiency separators that are able to collect droplets at submicron level. They are available as cylindrical elements and can be manufactured in a broad range of materials.

Fiberbeds are produced as a dense packing of fiber (glassfiber, polyester fiber, carbon fiber) assembled between two concentric screens, foreseen of a flange on top or bottom for installation on a tube sheet. The elements are normally manufactured in one piece and can be installed through a manhole or vessel open end.

The Diffusion type candles (DC) use Brownian Diffusion, interception and impaction as their collection mechanism and can collect essentially 99.95% of all submicron

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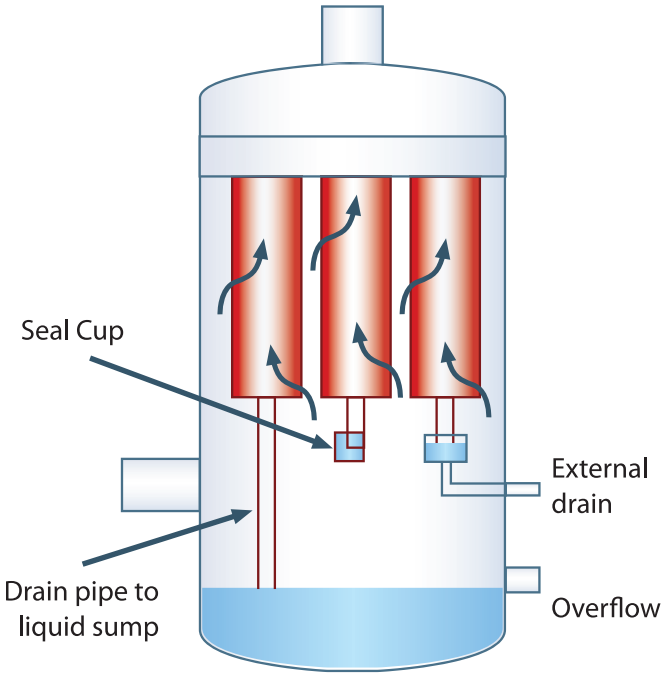
liquid particles and soluble solid particles. The pressure drop across the elements can range depending on the design from 25 to 500 mm W.G. (1-20 inch). Due to the principle on which these elements capture droplets, they have a virtually unlimited turndown capability, without loss in efficiency.

The Impaction type candles (IC) use only inertia based impaction as their liquid removal principle. These types of candles are designed to economically capture droplets in the range of 1-3 micron. The collecting efficiencies at these micron sizes range from 90 to around 97%. The pressure drop across the elements can range depending on the design from 100 to 250 mm W.G. (4-10 inch).



The operating principle is that a gas stream loaded with fine mist particles will enter the bed of densely packed fibres from one side, while from the other side clean gas will emerge and escape from the mist eliminator. The liquid, either separated by Brownian motion or Impaction, will be directed downwards of the candle towards the outer screen and will then drain off the downstream face of the fiber bed by gravity. Fiber bed mist eliminators are typically installed in a vessel or a tank and the collected liquid is continuously drained from within the tank.

Benefits

- **Extremely high liquid removal efficiency**
- **Unlimited turn-down capabilities without efficiency loss**

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PRODUCT PORTFOLIO – INLET DEVICES

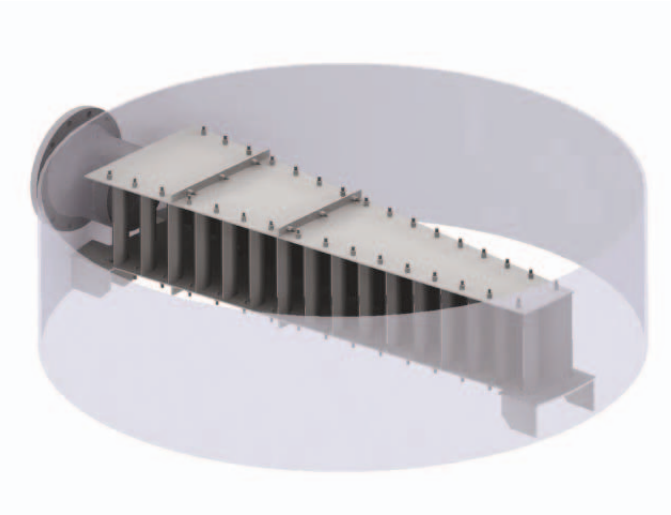
Vane Type Inlet Devices

Construction Materials

- Stainless steels
- Duplex steels
- Special alloys

Typical Applications

- Compressor suction drums
- Two- and three-phase separators
- Knock-out drums
- TEG contactors



Characteristics and benefits

Vane Type Inlet Devices are designed in such a way to ensure that the feed is entering the vessel in an ideal manner.

When a fluid stream strikes a solid surface, it reduces its momentum by exerting a force on that surface, and an equal but opposite force is exerted on itself. If this force is too great, liquid shatter can occur when the surface tension forces of the liquid are overcome. In order to avoid liquid shatter, different types of inlet devices have been developed which can reduce the momentum.

The sizing of nozzles is normally judged by the maximum $\rho.v^2$ value, which depends on the type of inlet device that's applied. Some examples of currently used values of ρv^2 throughout the industry for some of these types of inlet devices are as follows:

No inlet device or simple baffle: $\rho v^2 \leq$ 1,000 kg/ms²

Half-open pipe inlet device: $\rho v^2 \leq$ 1,500 kg/ms²

V-baffle: $\rho v^2 \leq$ 2,500 kg/ms²

Vane-type inlet device: $\rho v^2 \leq$ 15,000 kg/ms²

The reason that a Vane Type Inlet Device has a much higher maximum $\rho.v^2$ value than for example a plain nozzle, half-open pipe or V-baffle, is that it combines several positive effects:

- **Prevents liquid shatter**
  The surfaces which the inlet stream strikes are gently curved and the open area available for it increases as the flow passes through it. This gradual increase in area steadily reduces the stream velocity, and therefore the required rate of change of momentum, or exerted force, thus leading to a fall in the probability of liquid shatter.

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- **Evenly distributes the gas over the vessel area**

If an uneven distribution is present on the upstream face of the mist eliminator, it could flood due to a combination of localized high gas and liquid loading, and lead to possible excessive liquid carryover.

- **Avoids re-entrainment**

The gas will be diverted towards the vessel shell and upwards (not downwards as for example is the case with a half-open pipe), thereby avoiding turbulence in the liquid sump and liquid pick-up from the sump.

- **Enhances pre-separation of bulk liquid**

As the stream velocity is reduced, the liquid will enter the vessel in a calmer manner which will reduce the possibility of entrainment and therefore the liquid loading towards downstream separation equipment.

PRODUCT PORTFOLIO – INLET DEVICES

Slotted T-shaped Inlet Devices

Construction Materials

- Stainless steels
- Duplex steels
- Special alloys

Characteristics and benefits

The slotted T-shaped distributor consists of a horizontal tube stretching inside the vessel. Perpendicular to the horizontal tube is a pipe with rectangular slots increasing the area for the gas/liquid to enter the vessel, and thereby ensuring a reduced stream velocity. This will minimize liquid shatter and will have a positive effect on the downstream separation.

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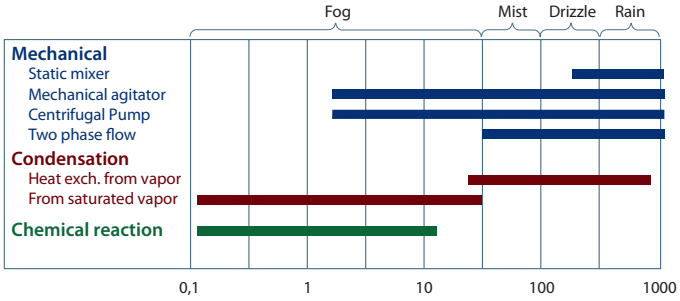
LIQUID-LIQUID SEPARATION

Principles

Principle of mixture formation

In many processes where liquids are coming into contact with each other, they mix. This can be an unwanted result or caused in order to enhance mass transfer processes or to create a chemical reaction. However, mixtures are virtually never economically interesting and therefore need to be separated.

Same as when a liquid is entrained in a gas, the source of mixture formation can be a dynamic process, a thermal process, or a chemical reaction. Depending on the kind of process and the way the droplets of the dispersed phase are formed, they can have a very different size as shown in the below table which gives an overview of the different sources of droplet formation and an indication on the respective range of droplet size of the dispersed phase.



Liquid-liquid separation systems provided by Omega Separations prove to be an effective solution in many applications such as:

- Acid alkylation plants
- Fractionator overhead reflux drums
- Three-phase separators
- LPG-Amine contractors

Principle of separation

The most common methods for separating liquid-liquid mixtures are gravity settling, enhanced gravity settling and coalescing.

A common gravity settler is solely based on the principle of Stokes law predicting the rate of rise or fall of droplets from one phase to the other and vice versa, mainly determined by the density and viscosity of both phases. The gravity settler has no internals installed and often the flow rate which can be allowed through it is too low to be economical, or the separation is not sufficient resulting in contaminated product.

Therefore enhanced gravity settling is applied. This relies on the same principle as gravity settling but introduces internals in the settler which will:

- reduce turbulence: either by increasing the pressure drop or by artificially reducing the effective vessel diameter and therefore the Reynolds number

- reduce the droplet settling distance

- provide multiple contact interfaces for droplets to coalesce

However, sometimes the circumstances are such that sufficient separation of both phases cannot be obtained by gravity forces alone. In those cases the size of droplets needs to be increased and a liquid-liquid coalescer needs to be applied or added to the enhanced gravity settling internals in order to obtain the required separation. A coalescer is a medium with a large surface area, creating a large number of contact interfaces for droplets to deposit, join and grow to larger droplets which will settle much faster.

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Design advice

The separation of two liquids can be influenced by many factors. A small amount of a solvent or surfactants (ppm or even ppb) might unexpectedly complicate the coalescing of the dispersed phase. Therefore, it is imperative to receive as much detailed process data as possible. Furthermore, the separation efficiency will be affected by the droplet distribution. Because of this complexity, a theoretical calculation describing the separation of two liquids can only be done based on assumptions of pure liquids, which never occurs in reality. Therefore, the selection and design of liquid-liquid separation equipment is based on a combination of basic principles, experience and trial testing. We therefore strongly recommend discussing all issues concerning liquid-liquid separation with an experienced Omega Separations engineer.

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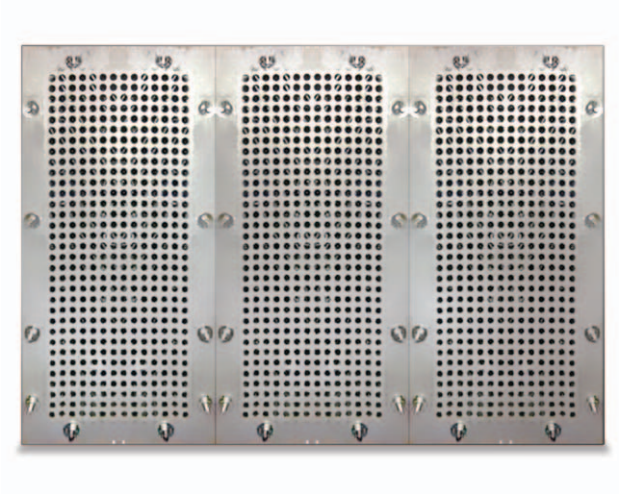
PRODUCT PORTFOLIO

Liquid Distribution Baffles

Construction Materials

- Stainless steels
- Duplex steels
- Special alloys



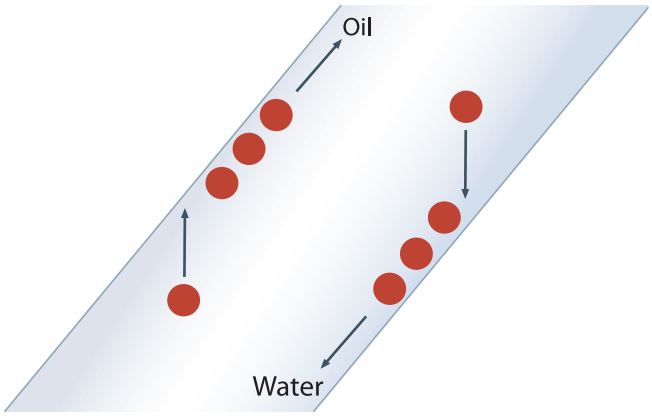
Characteristics and benefits

The easiest – but often very effective – method to reduce flow turbulence is by installing a liquid distribution baffle. This is a perforated plate designed with a certain open area to suit the given process conditions and vessel lay-out. The aim is to have the liquid mixture enter the separation equipment in laminar flow regime which will enhance the settlement of droplets.

Plate Packs

Construction Materials

- Stainless steels
- Duplex steels
- Special alloys



Characteristics and benefits

Plate packs are manufactured as a series of parallel or corrugated plates, designed to enhance the gravity separation as much as possible. The parallel plate packs are ideal in fouling circumstances but have a slightly lower efficiency compared to corrugated plate packs. Various plate spacings can be used in combination with variation in the vane angle in order to cope with various flow conditions.

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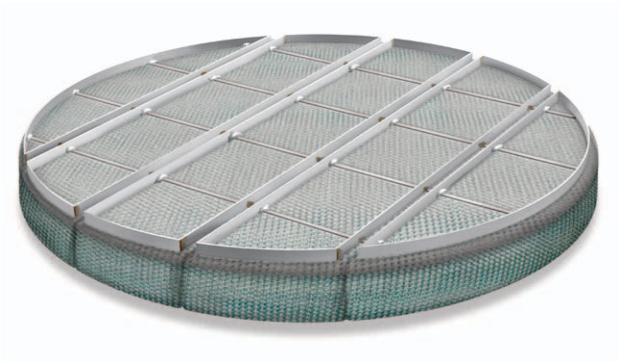
Wire Mesh Coalescers

Construction Materials

- Stainless steels
- Duplex steels
- Special alloys
- Plastics (PP, FEP, ETFE, ECTFE)
- Fibrous components (PTFE, Polyester, Glass fibres)



Characteristics and benefits

Wire mesh coalescers often consist of a combination of wires and fibers in order to create a maximum surface area for droplets to coalesce. In many cases the wire and fiber are from a different construction material, where one is hydrophilic (e.g. metal) and the other is hydrophobic (e.g. polyester) which enhances the separation. Studies have shown that there is an increased coalescence effect at the junction point between both materials. Therefore using both the metal and plastic materials will increase coalesce efficiency significantly.

Slotted T-shaped Inlet Devices

Construction Materials

- Stainless steels
- Duplex steels
- Special alloys

Characteristics and benefits

The slotted T-shaped distributor consists of a horizontal tube stretching inside the vessel allowing the liquid to enter the vessel at the ideal elevation. Perpendicular to the horizontal tube is a slotted pipe with large holes or rectangular slots ensuring a reduced stream velocity, which will minimize the flow turbulence and consequently have a positive effect on the downstream separation.

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