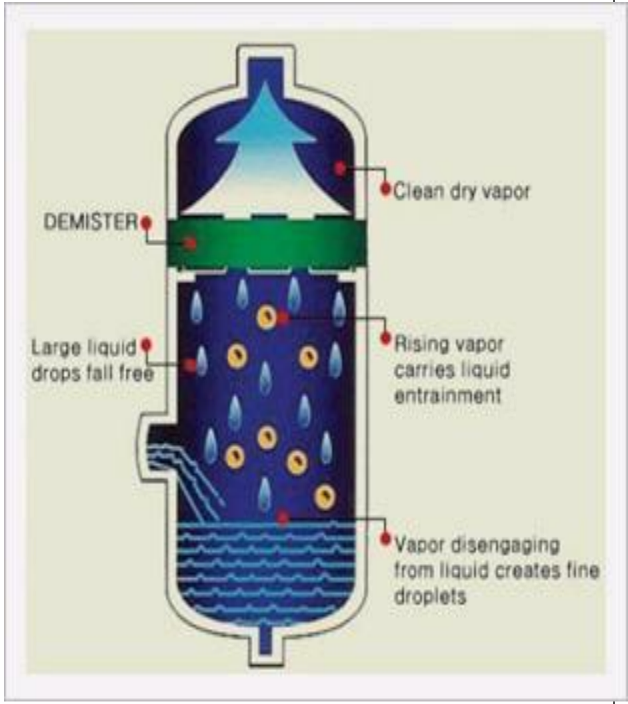
Flash Vaporization
Design of Knock-out Drum

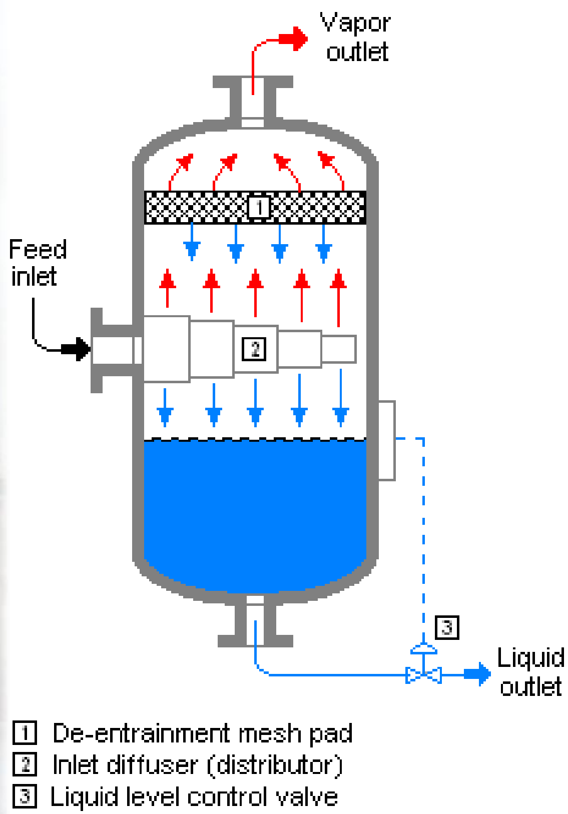
Introduction

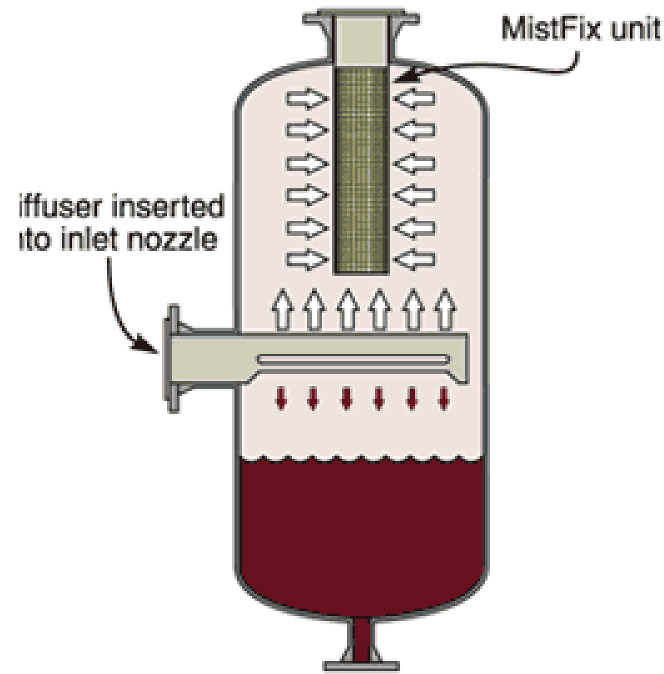
- **A Knock-out drum is a vapor-liquid separator in which the liquid droplets are separated from a liquid-vapor mixture (a flashing liquid).**



- **The liquid is separated by gravity, falls to the bottom of the vessel, and is withdrawn.**
  - **The vapor travels upward at a design velocity which minimizes the entrainment of any liquid droplets in the vapor as it exits the top of the vessel.**

Introduction





Introduction

- Without a mist eliminator, A simple knockout drum can remove droplets larger than about 380 microns by gravity settling.
- Generally, gravity settling removes more than 90% of the liquid entering the vessel.
- The remaining droplets smaller than 380 microns can be significantly removed by a mist eliminator in the top of the knockout drum (down to a diameter of 6 microns or less, depending on the type of mist eliminator).
- A knockout drum with mist eliminator can achieve an overall efficiency of 99.99% liquid removal.

Configuration

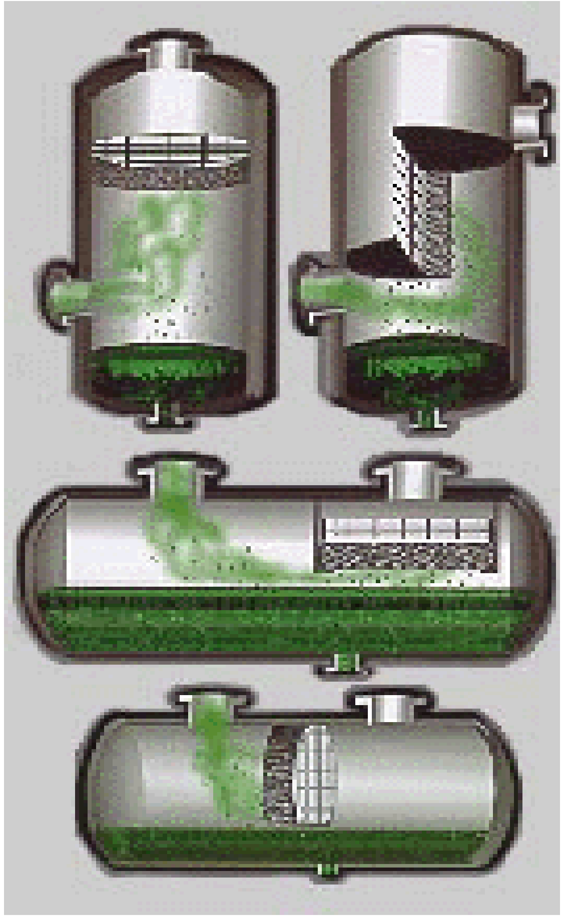
- **Knockout drums (also called flash drum) may be oriented vertically or horizontally.**

- **In both types, the mist eliminator may also be oriented vertically or horizontally.**

- **For a vertical mist eliminator (horizontal vapor flow), the drainage flow is cross-current, whereas for vertical upflow the drainage flow is counter-current.**

Configuration

- **Because cross-current flow results in less liquid holdup, a vertical mist eliminator can be operated at a higher vapor loading without re-entrainment (depending on the liquid load and on the height).**



Design

- The size of a vapor-liquid separator drum (or knock-out pot, or flash drum, or compressor suction drum) is dictated by the anticipated flow rate of vapor and liquid from the drum.

- In general, vapor velocity is the dominating factor in determination of the vessel diameter

Design

- **Souders-Brown equation, which is based on force balance on a droplet falling through vapor is employed to determine the maximum allowable vapor velocity:**

$$V = k\sqrt{\frac{\rho_L - \rho_v}{\rho_v}}$$

where:

V = maximum allowable vapor velocity, m/sec

ρ_L = liquid densty,

ρ_v = vapor density,

Design

“k” is called “vapor loading factor”, which is largely independent of the system variables (molecular weight, pressure, temperature, density, viscosity, surface tension, etc.).

Reliable estimation of vapor loading factor is crucial in sizing the flash drum.

Note: Knock-out drum manufacturers usually have their own data base for the determination of “k” values and you are recommended to used their values if you are ordering the drum from a specific manufacturer.

Design

"k" values can be estimated from Blackwell (1984) correlation

$$k = \exp[A + B\,ln(F_{lv}) + C\,ln(F_{lv})^2 + D\,ln(F_{lv})^3 + E\,ln(F_{lv})^4\}$$

$$F_{lv} = \frac{W_L}{W_v}\sqrt{\frac{\rho_v}{\rho_L}}$$

Where W_L and W_V are liquid and vapor mass flow rates and A, B, C, D, and E are constants:

A= - 1.877478097, B = - 0.8145804597, C = - 0.1870744085
D = - 0.0145228667, E = - 0.0010148518

K is usually between 0.1 and 0.35

Design

- **Using the known vapor flow rates and vapor velocity, the diameter of the drum can be estimated.**

- **For vertical flash drums the to length/diameter ratio (L/D) ranges between 3 – 5.**

- **The optimum value within this range can be estimated by minimizing the cost.**

Design

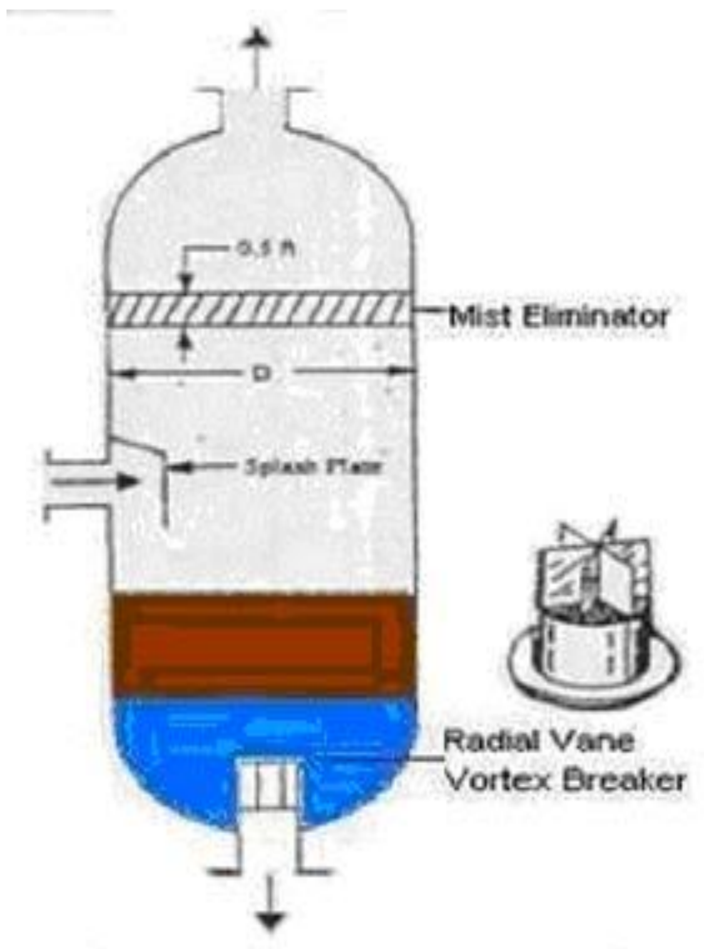
- **If (L/D) is larger than 5, a horizontal flash drum should be used.**

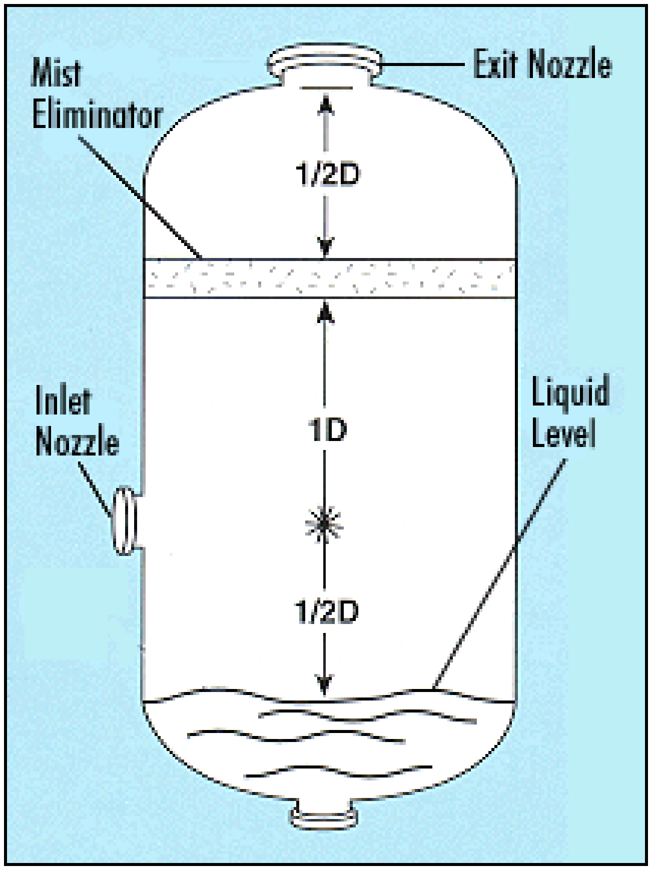
- **"k" values in horizontal flash drums are estimated as;**

$$k_{horizontal} = 1.25k_{vertical}$$

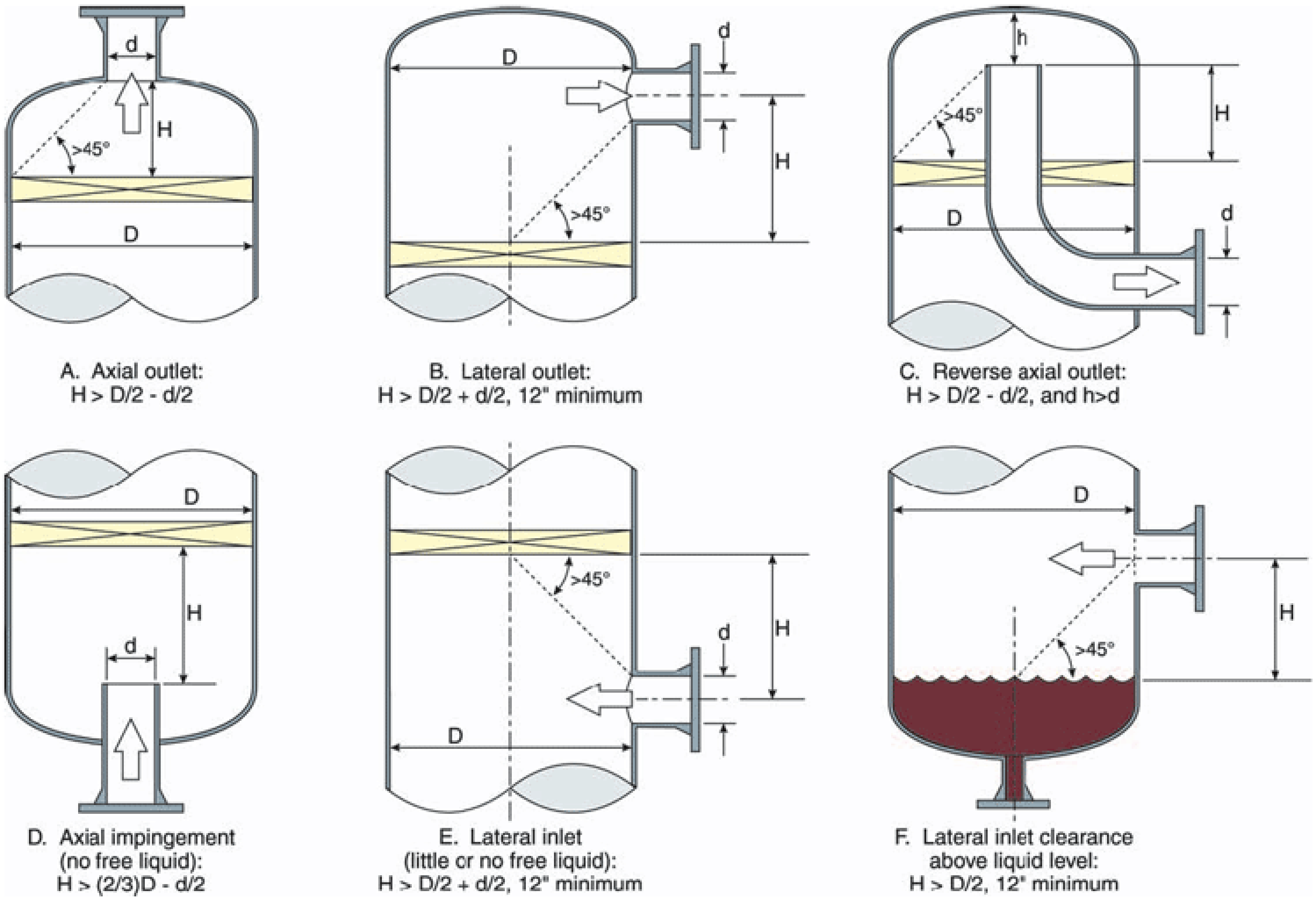
- **Horizontal drums are useful for high liquid flow rates.**

Design


0.5 ft
Mist Eliminator
D
Radial Vane
Vortex Breaker


Mist
Eliminator
Exit Nozzle
1/2D
1D
Inlet
Nozzle
1/2D
Liquid
Level

KO Design


d
H
>45°
D
A. Axial outlet:
H > D/2 - d/2
D
d
H
>45°
B. Lateral outlet:
H > D/2 + d/2, 12" minimum
h
H
>45°
D
d
C. Reverse axial outlet:
H > D/2 - d/2, and h>d
D
H
d
D. Axial impingement
(no free liquid):
H > (2/3)D - d/2
>45°
H
d
D
E. Lateral inlet
(little or no free liquid):
H > D/2 + d/2, 12" minimum
D
H
>45°
F. Lateral inlet clearance
above liquid level:
H > D/2, 12" minimum

Demisters

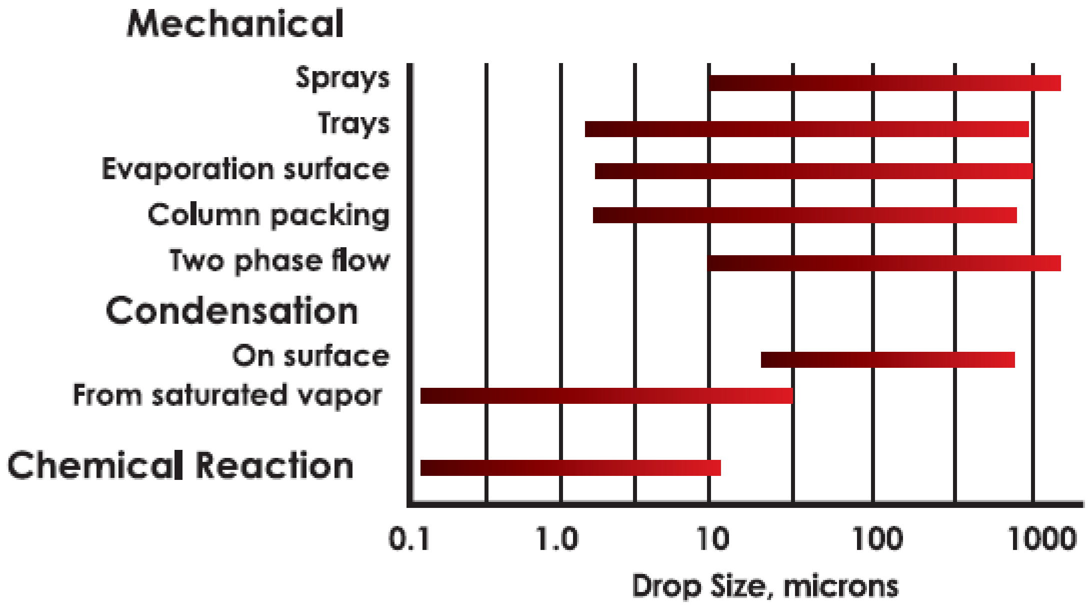
- **The formation of mists in gas streams often results in process inefficiencies and/or product loss in equipment such as knockout drums, distillation columns, evaporators, and environmental scrubbers.**

- **Mists can also cause serious damage to downstream equipment.**

- **Compressors may fail if liquid droplets are not separated from the gaseous input stream**

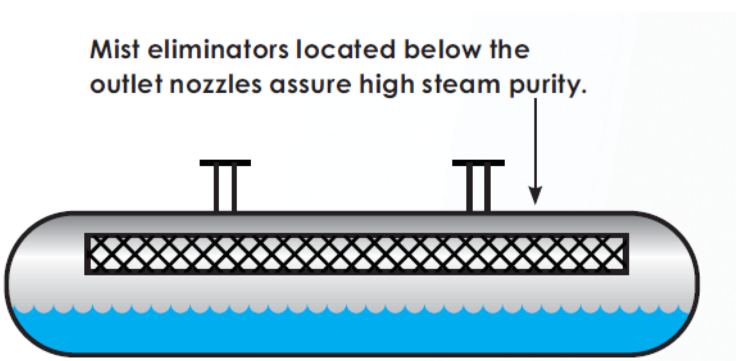
Demisters

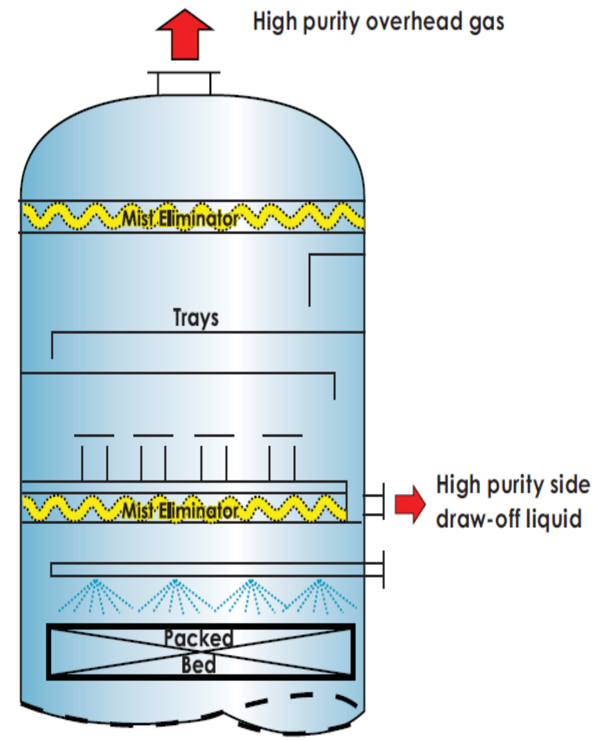
- **Entrainment is generated by one or more of three basic mechanisms:**
- **Mechanical action**
- **Chemical reaction**
- **Condensation**



Demister advantages

- A properly designed mist eliminator can:
  - Reduce loss of valuable chemicals
  - Increase throughput capacity
  - Improve product purity
  - Eliminate contamination
  - Provide equipment protection
  - Prevent air pollution

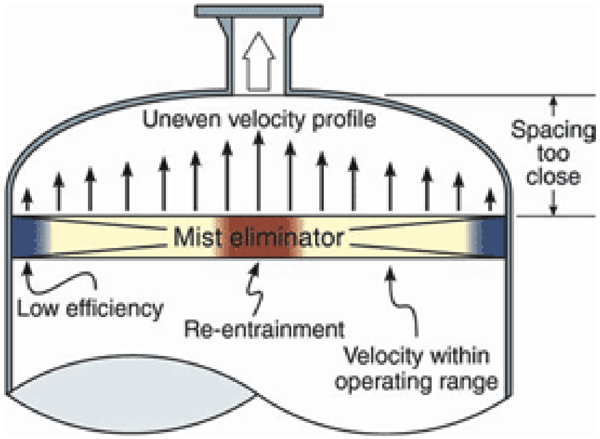


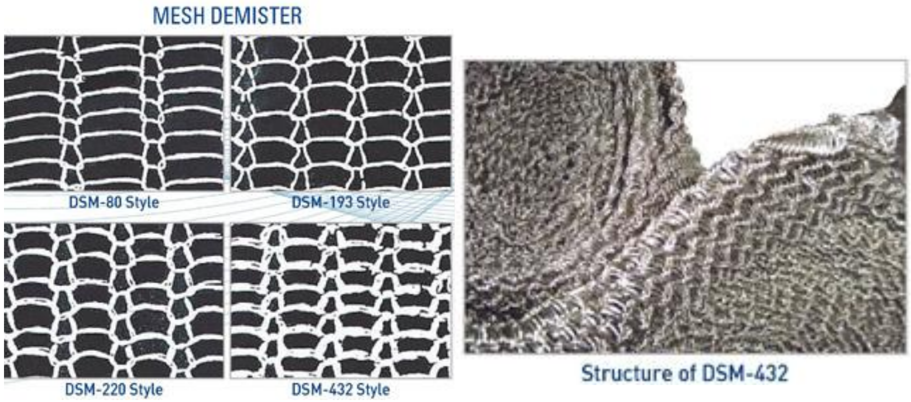


Demister selection guide

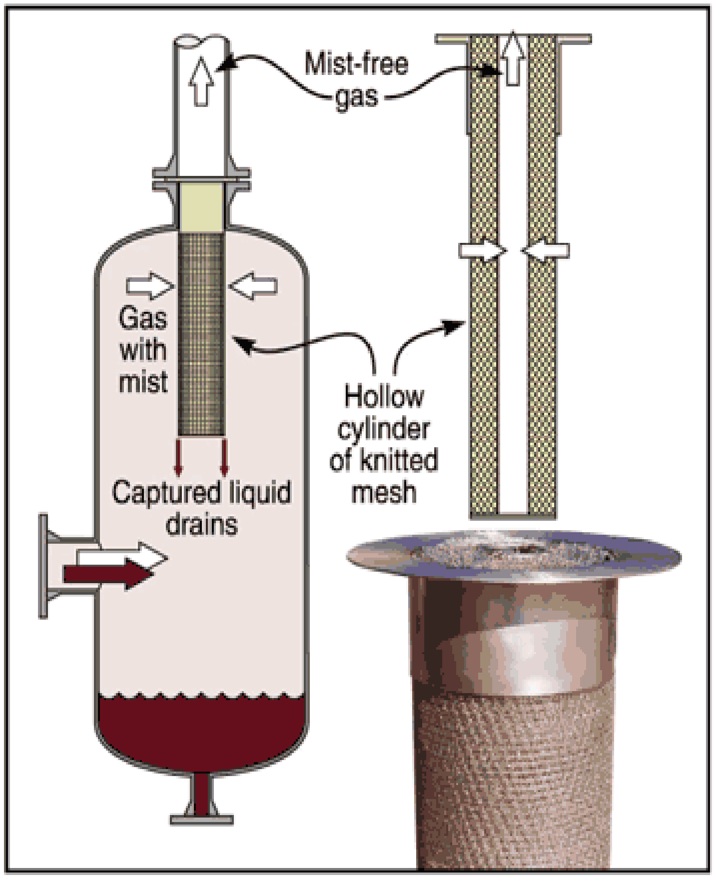
	Knitted Mesh	Vane	Fiberbed	Cyclone
Cost	1	2-3	10	3-5
Gas Capacity	5	6-15	1	15-20
Liquid Capacity	5	10	1	10
Particle Size (micron)	3-10	10-40	< 0.1	7-10
Pressure Drop, WC	< 25 mm (1")	<10-90 mm (0.4" - 3.5")	50-500 mm (2" - 20")	200-240 mm (8" - 14")
Solid Handling	3	10	1	8
Relative scale based on 1 as the lowest. Others are scaled.				

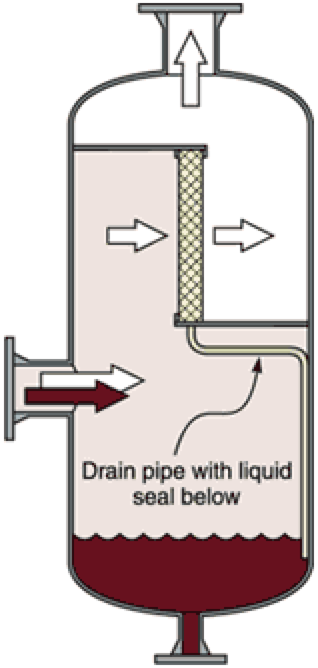
Horizontal demister



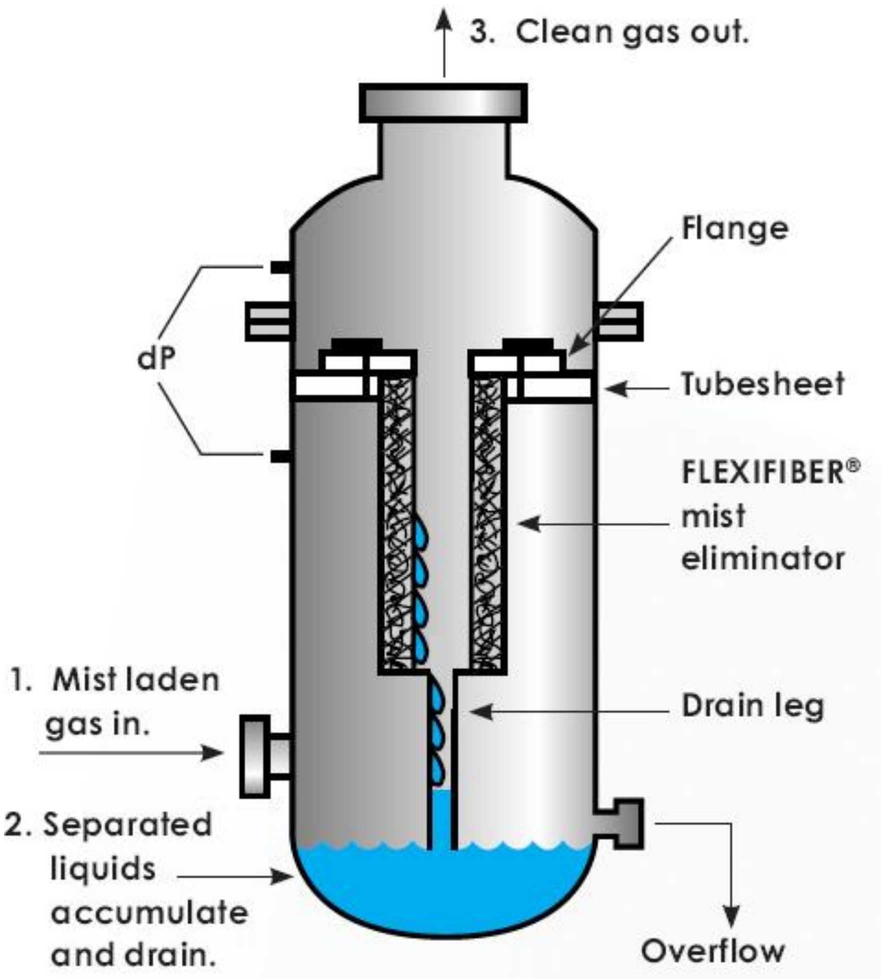


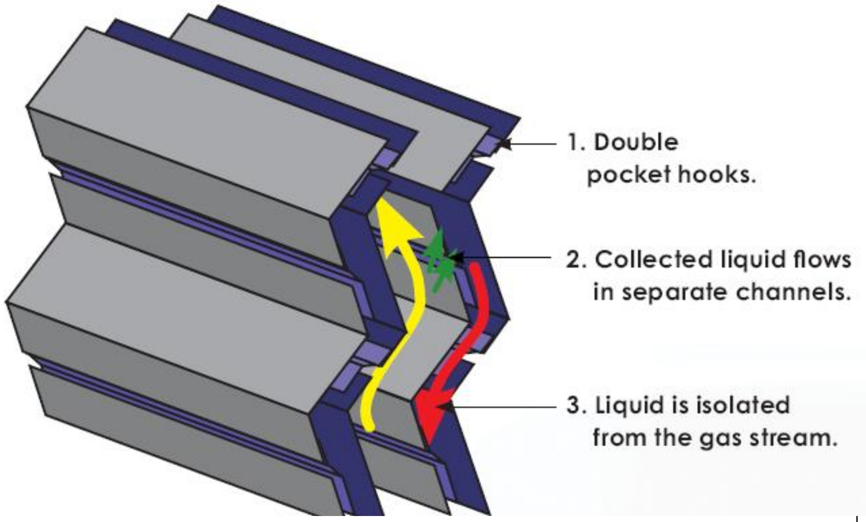
Vertical demister





Vertical demister

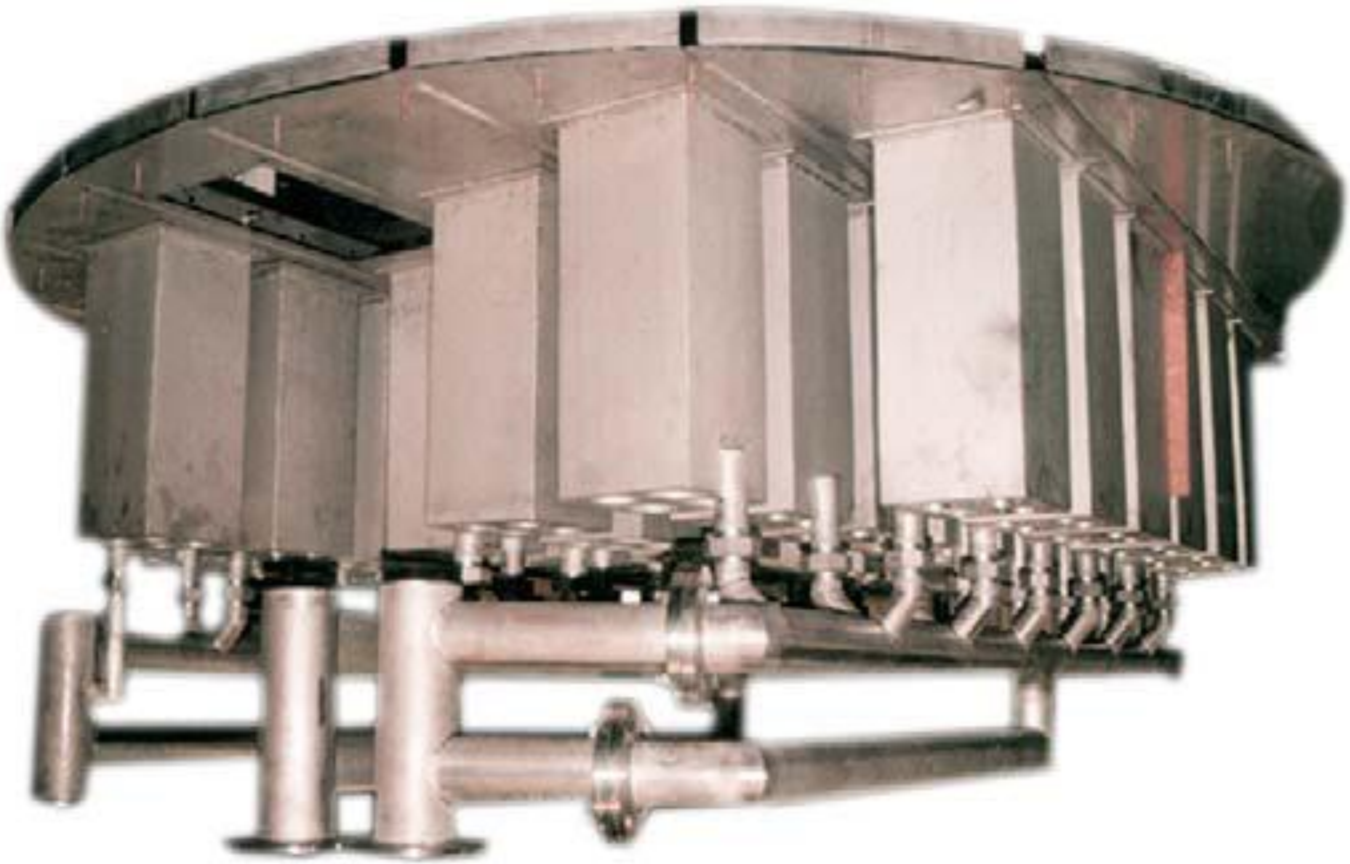




Cyclone mist eliminator

- Cyclone mist eliminators consist of multiple cyclone tube elements, mounted into a housing.
- The element diameter is selected based on process considerations. The units are provided in easily handled subassemblies, which are installed through vessel man ways.
- The most important benefits of this design are its very high gas handling capacity combined with excellent droplet removal efficiency even at elevated pressures.

Cyclone mist eliminator



Cyclone mist eliminator

Benefits of High Capacity Cyclone Mist Eliminators

- Minimizes new vessel diameter and weight, which is particularly important in high pressure applications

- Ideal for debottlenecking existing separator capacity upgrades

- High efficiency separation of <10 micron droplets, even at high pressures

- High gas turndown

- Easily installed through vessel manways

Demister Design

- **Select a proper mist eliminator regarding the process and droplets stickiness.**

- **Use manufacturers, design data which is usually graphical presentation of efficiency vs. Droplet size and pressure drop against vapor velocity.**

- **Demister pressure drop may affect the knock-out drum operation.**

Demister Design

- **In arriving at an optimum design, it is often necessary to make a compromise between removal efficiency on one hand and pressure drop and plugging tendency on the other.**

- **Design Parameters**
  - **Gas and liquid properties**
  - **Pressure**
  - **Quantity of entrainment and solids**
  - **Desired performance**

Questions?