ask AMACS
about phase contacting & separation issues

We need a mist eliminator in that knockout drum!

Can we add one without overhauling the vessel?

IT'S A SURPRISINGLY COMMON problem in refineries, petrochemical plants, gas plants, and similar facilities. A vertical knockout drum, such as the one shown in Figure 1, removes free liquid from a certain gas stream. In many such vessels, a mist eliminator is provided to remove fine droplets of liquid suspended in the gas. The conventional arrangement is a mesh pad located immediately below the gas exit as in Figure 2. However, at the time the plant was built, that precaution was not considered necessary in this particular knockout drum. Now mist is carrying over and causing trouble downstream.

The conventional solution is simply to add a mist eliminator as shown in the diagram. That would be feasible if the drum had a manway for worker entrance or a full body flange at the top, both shown in Figure 2. However, this particular vessel was not provided with either of those features. Thus, adding a conventional mist eliminator would require cutting the vessel open, at considerable cost in terms of dollars and down time.

Figure 1. Typical vertical knockout drum

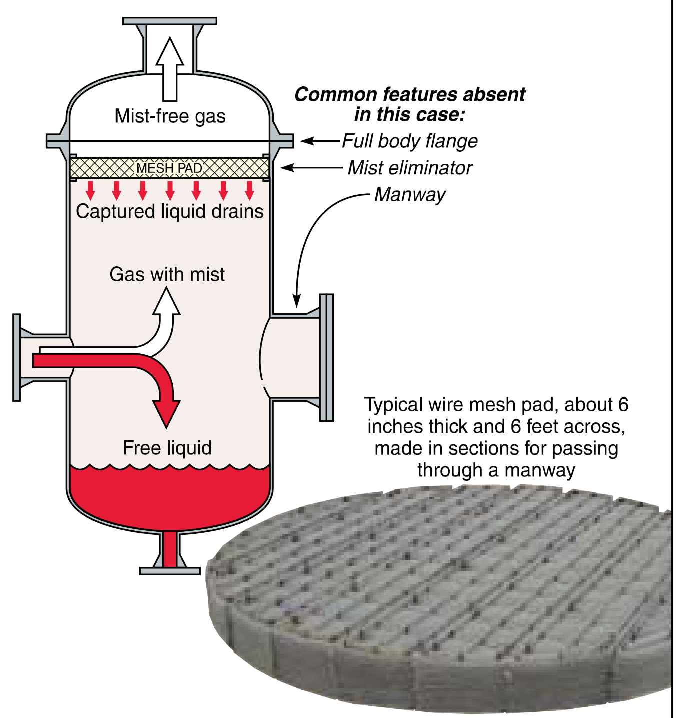


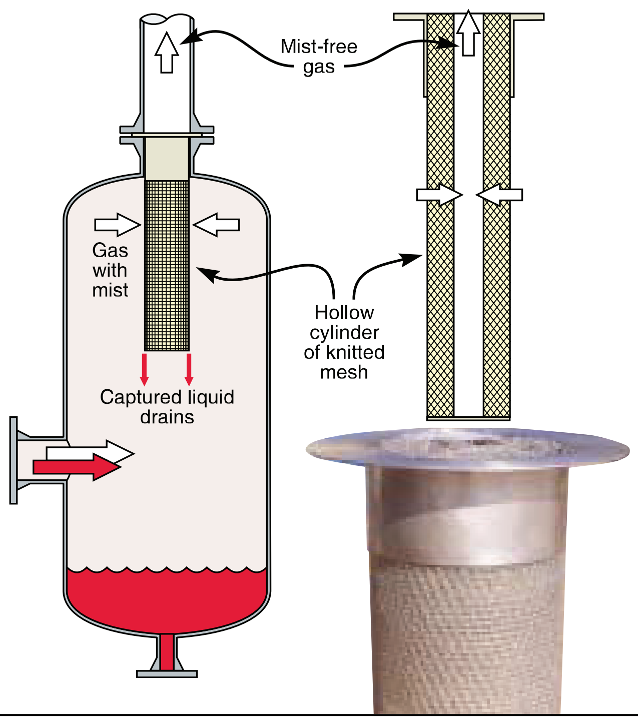
Figure 2. Knockout drum with conventional mesh-type mist eliminator, manway, and body flange

AMACS
PROCESS TOWER INTERNALS

A potential solution: the MistFix® mist eliminator

However, there is another solution that works in many cases such as this. It is a patented type of mist eliminator manufactured by AMACS Process Tower Internals called MistFix™ (U. S. patent number 5,985,004). As seen in Figure 3, a MistFix unit is a hollow cylinder of the same sort of knitted mesh that conventional mesh pads are made of. It is designed to be inserted in a vertical flanged gas exit nozzle, being secured by a base ring that fits between the flanges. Rigidity is provided by a cylindrical frame around which the mesh is wrapped (not shown in the diagram), and the bottom end is closed by a plate. MistFix units are widely applicable for exit nozzles with inside diameter no less than about 6 inches, provided that the length necessary to achieve an efficient gas velocity range is no greater than about 54 inches. By use of special high-efficiency high-density mesh styles, the radial thickness of the mesh can be as low as two inches - sometimes even less.

Figure 3. MistFix® insertion mist eliminator



A MistFix mist eliminator functions in the same manner as a mesh pad mounted vertically, such as in the knockout drum shown in Figure 4. Gas flows horizontally through the mesh, and captured liquid drains downward. In a MistFix unit as in Figure 3, mist-free gas emerges from the mesh into the central cavity and flows upward into the gas exit pipe.

The MistFix unit is sized to fit closely inside the exit nozzle. Its length depends on the case at hand. The longer the mesh cylinder, the greater the cross-sectional area of the mesh for gas flow, and the lower the gas velocity for a given volumetric throughput. The length of the mesh cylinder is selected so that the velocity through the mesh is within an optimum range for the application.

MistFix units can be advantageous for retrofitting even large vessels that have manways. This method avoids the usual down time and expense for installing a conventional mist eliminator. There is no need to purge and ventilate the vessel, build a scaffold inside, weld supports for the mist eliminator, and recertify the vessel to ASME code.

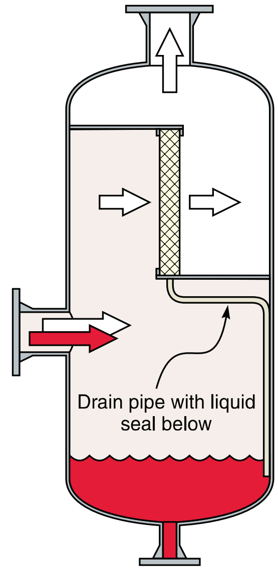


Figure 4. Gas flows through the mesh of a MistFix unit horizontally, as it does through a vertical flat mesh pad in some knockout drums such as this one.

Vessels with special linings for corrosion resistance but no mist eliminators are especially appropriate candidates for retrofit with MistFix units. If increased throughput causes mist and the need for a mist eliminator, it is difficult to attach a support ring without penetrating the lining. Even slight damage to the lining can lead to corrosion and possible failure of the vessel. A MistFix unit may be the only viable alternative.

Even for new construction, MistFix mist eliminators are preferred over conventional alternatives in some cases. One instance is applications requiring frequent replacement because of fouling or corrosion. Another is those in which entering the vessel for inspection and replacement would be burdensome because down time cannot be tolerated, or the process material is exceptionally hazardous, etc.

Despite the advances that have been made in the technology, there is still as much art as science in the design and specification of mesh and vane mist eliminators. For all but the most experienced users, proper application depends on consultation with the manufacturer's engineers. This is especially so the case of MistFix mist eliminators.

This paper provides some background for those discussions with AMACS engineers. Included are some general guidelines for applying MistFix mist eliminators particularly in retrofits. The information is not intended to enable users to design and specify these devices without assistance.

Applying general mist eliminator design to a MistFix unit

Although MistFix mist eliminators are cylindrical, they are designed and specified for an application by the same methods as conventional flat mesh and vane units. The overall general procedure is as follows:

1. Estimate the size distribution of mist droplets.
2. Specify the required separation efficiency in terms of the percent of mist to be removed.
3. Considering droplet size, mist load, liquid characteristics, and the characteristics of various mesh types in terms of droplet capture efficiency, corrosion resistance, mist load capacity, and wettability by the mist liquid, tentatively

choose a mesh style and material and the radial thickness of the cylindrical mesh pad to achieve the required separation at optimum gas velocity.

4. Choose a design value for the vapor load factor K that is appropriate for the foregoing assumptions, and calculate the optimum design velocity through the mesh using the Souders-Brown equation (explained next).
5. Based on the optimum velocity, the expected volumetric throughput, and the assumed diameter of the MistFix unit, calculate the necessary cross-sectional area for gas flow through the mesh and thus the length of the unit (also explained below).
6. Estimate separation efficiency and pressure drop within the required turndown range.
7. If the estimated results are not acceptable, repeat steps 3 through 6 with a different mesh style, material, or thickness, or with a different diameter of the MistFix unit if that option is available.
8. Check for conformance with internal gas flow guidelines and for height available for the MistFix unit inside the vessel, and revise as necessary.

For explanations of those methods as applied to a broad range of devices, see Amacs literature such as "AMACS Mesh & Vane Mist Eliminators."

Regarding Step 3 above, a very wide variety of mesh types are available for conventional pads and MistFix units. Standard wire diameters are 0.011 inch and 0.006 inch. Standard alloys are 304 and 316 SS, but others such as Inconel and Hastelloy are often supplied for certain corrosive services Plastic monofilaments include polypropylene and Teflon Yarns co-knit with metal or plastic mesh for capturing very fine mist droplets are commonly provided in Dacron, glass fiber polypropylene, and Teflon. It may be that the optimum mesh selection is a combination of different types. For instance, an outer layer of fine, dense mesh or co-knit yarn may serve to coalesce very small mist droplets, forming larger entrained droplets that are in turn captured by an inner layer of coarser bare mesh.

Efficiency and pressure-drop estimations (Step 6 above) are beyond the scope of this paper typically requiring consultation by Amacs engineers. The full spectrum of efficiencies can be provided by a MistFix unit, from a general-purpose efficiency of 99% of 10-micron and larger droplets to a high efficiency of 99.9% of 2-micron and larger droplets. Typically the pressure drop across a MistFix device is 2 to 4 inches of water column.

Step 4 above is conducted for a MistFix unit in the same way as for a conventional flat mist eliminator. These devices are sized for cross-sectional area to achieve a design velocity according to the Souders-Brown vapor load factor K:

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

V_G = Gas velocity (volume flow divided by cross-section)
ρ_L = Liquid density
ρ_G = Gas density

The design velocity is the value of the superficial or average gas velocity through the mesh (volumetric flow rate divided by cross-sectional area) that is optimal for the particular liquid and gas involved. It is intended to lie about 10% below the upper end of the operating velocity range. That upper end is the point at which increasing gas velocity begins to cause excessive re-entrainment of captured liquid from the mesh. The lower end of the operating range, in turn, is the point at which decreasing gas velocity begins to cause unacceptably poor droplet capture efficiency.

The Souders-Brown equation allows experimental data taken with air and water on a certain mist eliminator to be generalized to the same type of device with gases and liquids having generally similar characteristics but different densities. Once a design value of the vapor load factor K is established for a mist eliminator type, the design velocity can be calculated for various combinations of gases and liquids.

The appropriate design value of K for a MistFix unit depends on a number of factors that are beyond the scope of this paper. As a first approximation in most cases, however, one can use the figure that is commonly recommended for vertical flat mesh pads: 0.42 feet per second. This K factor corresponds to a velocity of 12 feet per second in the reference case of water and air at room conditions.

It is assumed that the mist load is less than 0.1% volumetric, which is equivalent to 0.5 gpm per square foot at 10 feet per second. Greater mist loads require special considerations.

It is also assumed that the pressure in the vessel is between atmospheric and about 85 psig. The K value should be de-rated by 0.1 (24%) for each 100 psi increase above atmospheric pressure.

Sizing a MistFix unit

Applying the design velocity to size a MistFix unit (Step 5 above) is a bit more tricky than with a conventional flat mesh pad. In a flat pad, the velocity is the sameth roughout the pad-at least ideally to a first approximation. That velocity is simply the volumetric flow rate divided by the cross-sectional area of the pad, which is the same throughout the thickness of the pad. However, in the cylindrical mesh pad of a MistFix unit, the cross-sectional area through which the gas enters the mesh at the outer surface is larger than the area of the inner surface. (See Figure 5.) Thus, the velocity increases as the gas flows radially inward.

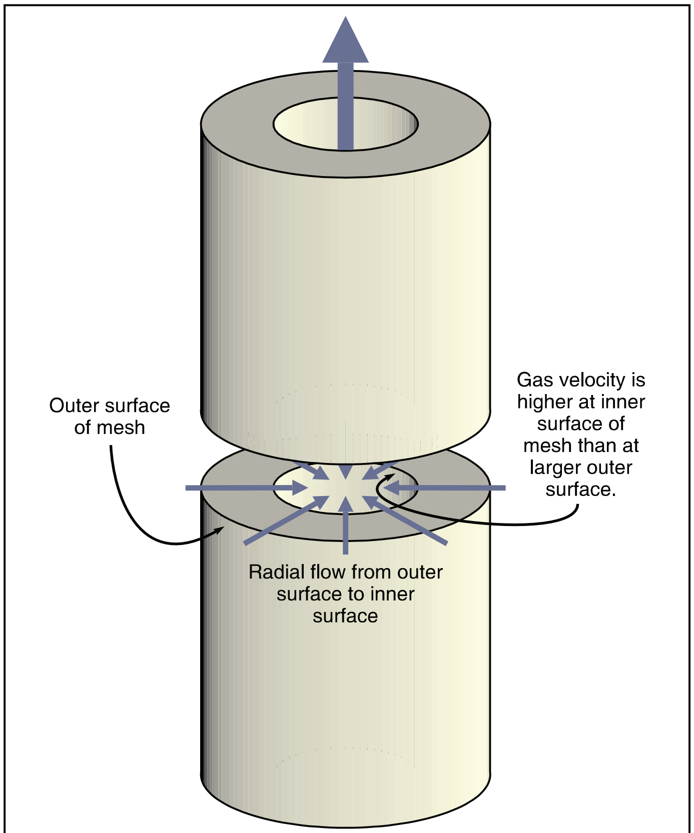
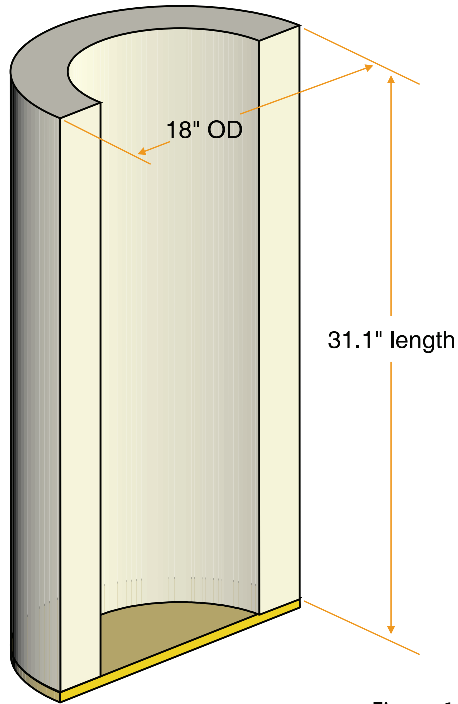


Figure 5. A special consideration in selecting a MistFix unit: higher velocity at the inner surface than at the outer



Sizing MistFix unit for knockout drum with exit nozzle inside diameter of 18 inches:

Liquid droplet density ρ_L = 42.5 lbs/ft^3
Gas density ρ_G = 0.31 lbs/ft^3

Design velocity $V_G = K \sqrt{(\rho_L - \rho_G)/\rho_G}$ = 11.7 K
Recommended design K is 0.42 ft/sec
V_G = (11.7)(0.42 ft/sec) = 4.91 ft/sec

Given a design vapor rate of 3,600 ACFM
Then the required cross-sectional area
= (3,600 ft^3/min)/(4.91 ft/sec)(60 sec/min) = 12.2 ft^2

If sizing is based on outside diameter
Flow area circumference = (π)(1.5 foot) = 4.712 ft

Design length = area/circumference
= (12.2 ft^2)/(4.712 ft) = 2.59 feet
= 31.1 inches length of MistFix unit mesh

Figure 6. Simplified sizing example

Depending on the judgment of the designer, the design velocity may be established at the inner or outer surface or anywhere in between. The most conservative and cautious approach is to set the inner-surface velocity at the design value, to make sure re-entrainment is avoided. Velocities farther out toward the outer surface will be progressively lower.

Figure 6 depicts the application of Steps 4 and 5 above to a typical simplified design case. A knockout drum with design throughput of 3,600 actual cubic feet per minute has an 18-inch gas exit nozzle. A MistFix unit is to be inserted in the nozzle, and the proper length is to be determined. The pressure is less than 85 psig. The flowing materials are hydrocarbon vapor and liquid with densities of 0.31 and 45.2 pounds per cubic foot.

Using a design K factor of 0.42 as discussed before, the design velocity turns out to be 4.91 feet per second. The cross-sectional area required to achieve that velocity is 12.2 square feet. For this MistFix unit, the length to achieve that design velocity at the outer surface is 31.1 inches. By comparison, if a conventional round horizontal mesh pad were used, that design cross-section would correspond to a diameter of 47.3 inches.

Height and flow considerations in the vessel

Special considerations for MistFix units are also involved in Step 8 above, regarding available vessel height and internal flow guidelines. The length of a MistFix device is of course constrained by the vertical space inside the vessel as well as the typical 54-inch maximum. The length limit is to allow good drainage of captured liquid, without excessive flooding in the lower end of the MistFix unit. Four and a half feet is a generally appropriate maximum for typical wire mesh, low-viscosity liquid, and a typical light mist load of about 0.1% volumetric. The length limit must be shortened for high viscosity, heavy mist loads, and high-density mesh.

Flow guidelines in turn, encompass two considerations: maintaining an even velocity profile throughout the length of the unit, and avoiding strong turbulence and fluid shear around and below the MistFix unit. Consultation by Amacs engineers is especially important in this area.

To prevent uneven flow through the mesh, the bottom end of the device should be well clear of the inlet stream - more than about half a vessel radius above the top of the inlet nozzle. In many cases, undesirable turbulence can be diminished by a properly selected inlet feed device. If a manway is not available for installing such a device, it may be possible to use a diffuser designed for insertion through the inlet nozzle as shown in Figure 7. To control flow inequality along the length of the MistFix unit, variation in thickness or density of the mesh may be incorporated.

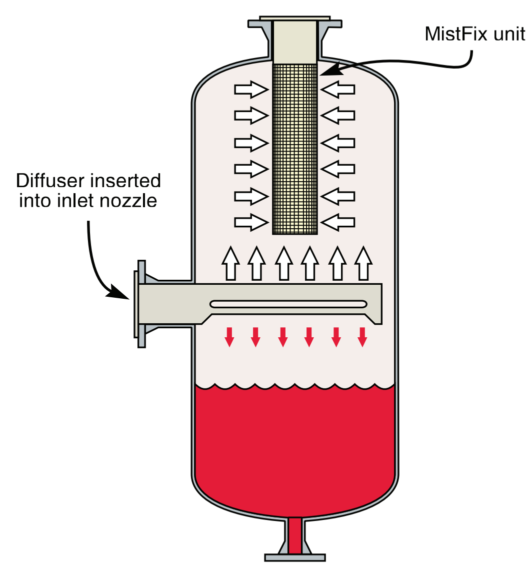


Figure 7. Use of an inlet feed device to help maintain even flow through a MistFix unit when it extends near the inlet nozzle of the knockout drum

In-line chamber for small gas exit nozzles

If the existing gas exit nozzle on the knockout drum is too small for inserting a MistFix unit, an in-line chamber can sometimes be provided for the device directly above the knockout drum as shown in Figure 8. This expedient comes into play when the exit nozzle diameter is smaller than the minimum 6 inches, or when the MistFix unit must be bigger than the nozzle to provide enough flow area within the available vessel height.

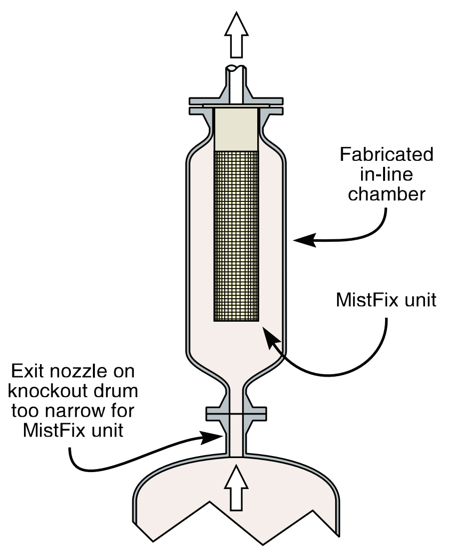


Figure 8. Mounting a Mist-Fix unit in a chamber above the knockout drum

In the special circumstances where this configuration is feasible, it provides all the benefits that a MistFix mist eliminator brings when inserted in a knockout drum. Conventional flat mesh pads and vane units can also be mounted in this fashion. However, in such cases, the chamber must be considerably larger than for an equivalent MistFix unit. Each application of this type is unique and requires consultation of Amistco engineers.

Case Histories

Chemical fiber plant reduces cleaning cycle

A Midwestern fiber production plant had to shut down two identical vertical gas-liquid separators four times a year to replace the horizontal mesh pads due to fouling with fibers. Each shutdown lasted two days because of the time required for ventilating the vessel and building a scaffold inside to reach the mesh pad. The plant was operating near maximum capacity, so any down time directly affected the company's bottom line.

The separators were 36 inches in diameter and 84 inches high. The incoming stream consisted of an off gas with a density of 0.25 lb/ft^3 and a throughput of 3,600 actual cubic feet per minute. The feed contained less than 0.1% water with droplets greater than 10 microns in size, and also traces of fibers. The gas outlet nozzle had an inside diameter of 12 inches.

Based on the process conditions, a 12- inch MistFix unit with a length of 30 inches for each separator, using 316 SS mesh. these devices have been operating very successfully for several years. The plant keeps spare MistFix units in inventory and can easily change a fouled MistFix in a few hours.

Refinery capacity increase and downtime reduction

A medium-size Midwestern refinery needed to increase the capacity of three knockout drums by 10%. At the same time, management was looking for ways to reduce the periodic down time of the vessels for replacing the horizontal mesh pads. The drums had an outside diameter of 60 inches and a height of 108 inches. For each vessel, the gas flow rate was 8,000 ACFM. The gas was fuel gas with a density of 0.15 lb/ft^3. The mist consisted of oil with a density of 50 lb/ft^3, the liquid load being less than 0.1%. The exit nozzles were 16 inches in diameter.

One of the knockout drums was chosen for retrofit with a MistFix unit on a trial basis. The design was for a diameter of 16 inches, a length of 48 inches, Monel for the mesh, and 316 SS for the frame. The device has been operating successfully for 16 months. Because of this positive experience, the refinery is considering MistFix units for the other two separators as well as additional applications in the plant.

Specialty chemicals plant with lined vessels

A specialty chemicals plant had increased its capacity over the years and was operating without mist eliminator pads in any of its vessels. Now frequent liquid carryover in several places required corrective action. Unfortunately, most of the vessels involved were lined for corrosion resistance. Adding a mesh pad would require welding a support ring to the vessel wall, entailing considerable expense to restore the lining.

A 36 inch long MistFix unit was designed for one of the vapor-liquid separators with 42-inch outside diameter and 108-inch height. The diameter of the gas outlet nozzle was 10 inches. The gas flow rate was 3,000 ACFM, and the gas density was 0.007 lb/ft^3. To resist corrosion, the mesh was made of Ni-200 and Teflon. Using a MistFix unit in the gas outlet avoided damaging the vessel lining. As a result of success in that retrofit the plant has ordered additional MistFix units for other lined vessels

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