

Compressor Suction Drums:

I think I've got liquid carryover.
What can I do about it?



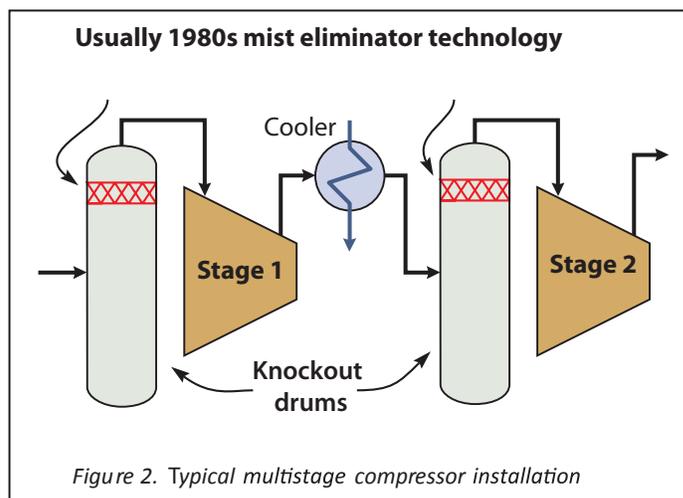
Figure 1. Typical compressor suction drums

IT HAPPENS in petrochemical plants, refineries, and anywhere else that the gas approaching a compressor is wet. Traces of aqueous or organic liquid escape the inlet knockout drum - often intermittently - and silently damage the compressor. Telltale signs include pitting corrosion, salt deposits, and diluted lubricants.

Instead of trying to repair symptoms, look for the root cause, which usually involves the mist eliminator in the knockout drum (Figures 1 and 2). Problems may include improper mist eliminator specifications, overloading, uneven velocity profiles, incorrect installations, high liquid viscosity, waxy deposits, liquid slugs, foaming, and several other possibilities.

The trouble may even be that no mist eliminator was provided in the first place - or perhaps no knockout drum at all. But wherever free liquid drops out in a suction drum, it generates some mist that can damage the compressor unless it is removed by a mist eliminator. Even in cases where the feed gas never has any free liquid, there are often fine mist droplets that coalesce into large drops on the walls of the inlet pipe or inside the compressor. For all but the driest gas, a compressor should be protected by an inlet mist eliminator. New high-capacity, high-efficiency mist eliminator technologies pay off the first time you avoid a shutdown.

For optimum separation performance, compressor knockout drums must be properly designed and sized with appropri-



ate mist eliminator elements in correct configurations, taking into account many factors. In multistage compressor installations, the proper knockout drum design is seldom the same for all stages. To maintain good performance, the design of each drum should be reviewed whenever there are significant changes in the process, such as increases or decreases in throughput, shifts in composition of the gas or mist droplets, alterations of upstream equipment, or revisions of operating and control procedures. In addition, mist eliminator elements should be visually inspected occasionally (especially after major process upsets) to make sure they are intact and free of excessive solid deposits.

A thorough understanding of the relevant considerations will help you avoid common suction-drum pitfalls - and some not-so-common ones - that could severely damage your compressors due to liquid carryover. For detailed explanations of mist eliminator selection, sizing, and vessel design for a wide range of applications, see Amacs literature such as AMACS Mesh & Vane Mist Eliminators brochure. This paper provides information that applies specifically to compressor inlet knockout drums.



Designing for droplet size distribution

There are many different types of mist eliminator elements, and the variety has greatly increased through the years. Not understanding the liquid source in the upstream process can cause you to select the wrong type of mist eliminator, or to keep a given type when process changes make it inappropriate.

Understanding the process allows you to design for the most efficient mist collection. Most important, selection should not be made until the droplet size distribution is defined, in terms of the proportion of droplets of each size. Assuming an incorrect droplet size distribution can mean that you have designed for a less efficient mist eliminator, and liquid carryover may occur.

Table 1. Diameter range of mist and other droplets

Particle Type	Size range (microns)
Large organic molecules	Up to 0.004 μm
Smoke	0.0045 to 1.0 μm
Condensation fog	0.1 to 30 μm
Atmospheric clouds and fog	4 to 50 μm
Generated by gas atomization nozzle	1 to 500 μm
Atmospheric "mist"	50 to 100 μm
Atmospheric "drizzle"	10 to 400 μm
Generated by boiling liquid	20 to 1,000 μm
Generated by 2-phase flow in pipes	10 to 2,000 μm
Atmospheric raindrops	400 to 4,000 μm

Table 2. Droplet sizes (water in air) typically captured with 99.9% efficiency by mist eliminator elements of various types

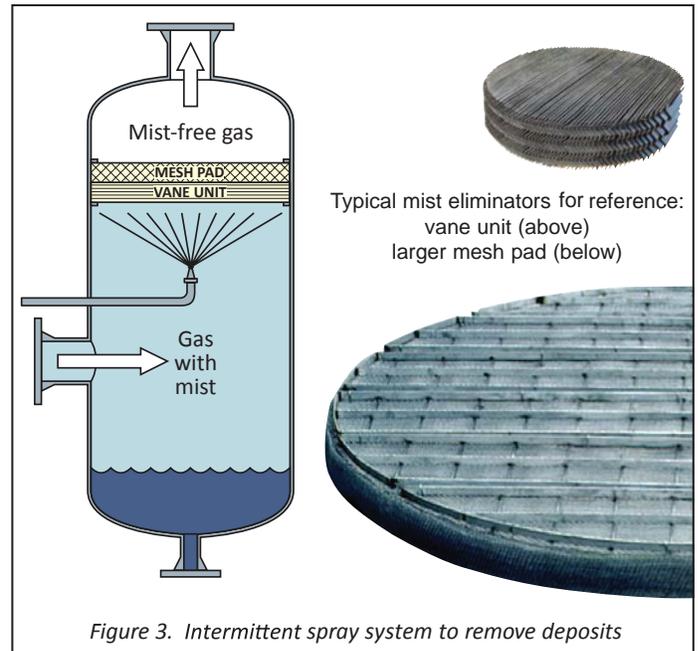
Element type	Size range (microns)
Fiber candles or panels	0.1 and larger
Mesh with co-knit yarn	2.0 μm and larger
0.006-inch knitted mesh	5.0 μm and larger
0.011-inch knitted mesh	10 μm and larger
Amistco double-pocket vane	10 μm and larger
Conventional vane arrays	15 μm and larger

See Tables 1 and 2 for some points of reference and rough guidelines in this respect. Be aware that the capture efficiency of a given mist eliminator element does not depend only on droplet size. It is also influenced by gas velocity through the element and mist load in terms of liquid flow rate per unit of cross-sectional area. Then there are variables such as density and viscosity that depend on temperature, pressure, and liquid and gas composition. All else being equal, efficiency generally goes up

with higher velocity, finer mesh strands, closer packing of mesh (greater density), closer spacing of vanes, and greater thickness of the mist eliminator element.

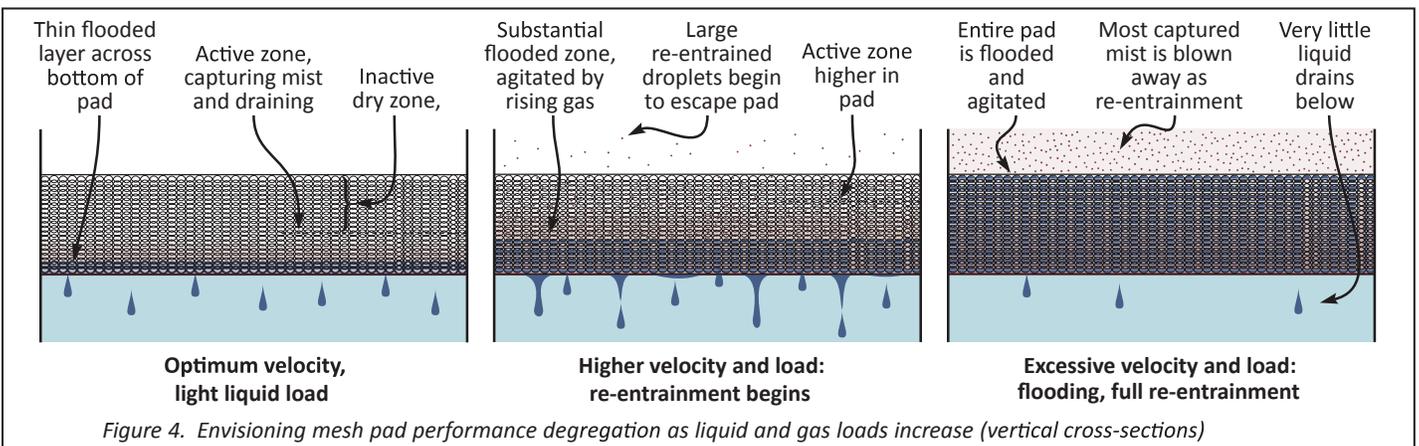
Mesh pad fouling

In some cases, liquid carryover to the compressor is caused by fouling of a mesh-type mist eliminator, on account of the resulting restriction of gas flow and extra holdup of liquid in the pad. Vane-type mist eliminators are a better choice for fouling applications. Due to the relatively wide open spaces between blades, vanes are much less likely to plug. If the fouling deposit can be readily dissolved by a suitable solvent, as might be the case with viscous oils or waxes or certain caked solids, consider installing a spray system as shown in Figure 3 to clean the vanes on-line whenever necessary. Adding a high-efficiency mesh mist eliminator downstream of the vane unit (also shown in Figure 3) can help make up for the inherently lower droplet capture efficiency of the vanes.



Liquid slugs and high liquid loading

In some applications, liquid slugs occasionally come in with the gas feed. These surges can temporarily overwhelm the slug-catching capability of the inlet knockout drum and flood a mesh-type mist eliminator, causing liquid carryover. (See Figure 4.)



Breaking inlet foam

If liquid in the gas approaching the compressor knockout drum is subject to foaming, it can readily flood a mesh pad and in severe cases even a vane unit. The end result is massive liquid carryover from the vessel and damage to the compressor. A vortex-tube cyclone device (Figure 5) can break up foam in the incoming feed.

Dealing with high liquid viscosity

There are applications in which high viscosity impedes liquid drainage so severely that a mesh pad would flood at prohibitively low velocities and liquid loading. In these applications, a vane unit is the better choice. For high efficiencies, consider AMACS multi-pocket vanes which handle high-viscosity liquids with an efficiency of 99.9% for 8-micron and larger droplets.

Mist eliminator spacing in the vessel

An often overlooked but very important aspect of suction drum design that can lead to liquid carryover is proper spacing in the vessel. Figure 6 illustrates guidelines for sufficient distance between the mist eliminator and the gas inlet and outlet.

If spacing is too close, the gas will pass through only part of the mist eliminator. This causes localized high velocities with

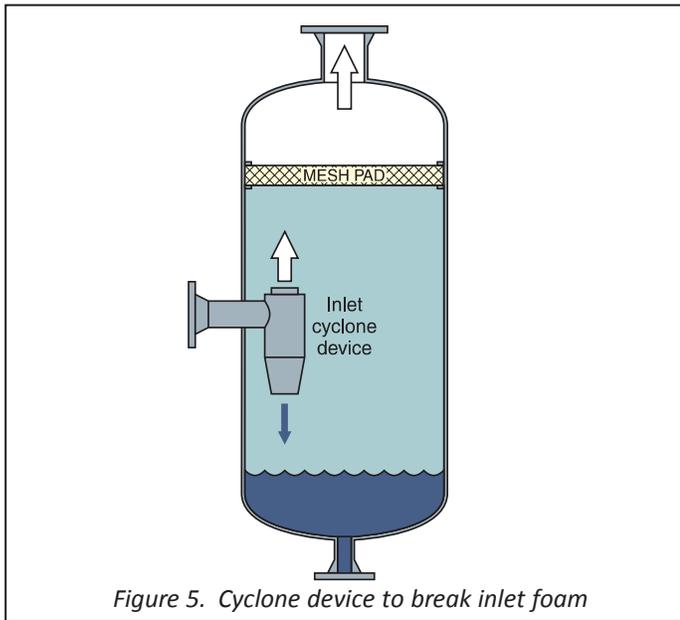


Figure 5. Cyclone device to break inlet foam

When liquid slugs or generally high liquid loading are expected, it is recommended to use a vane-type mist eliminator upstream of the mesh pad as shown before in Figure 3. Vanes can generally handle up to 10 times more liquid load than mesh pads.

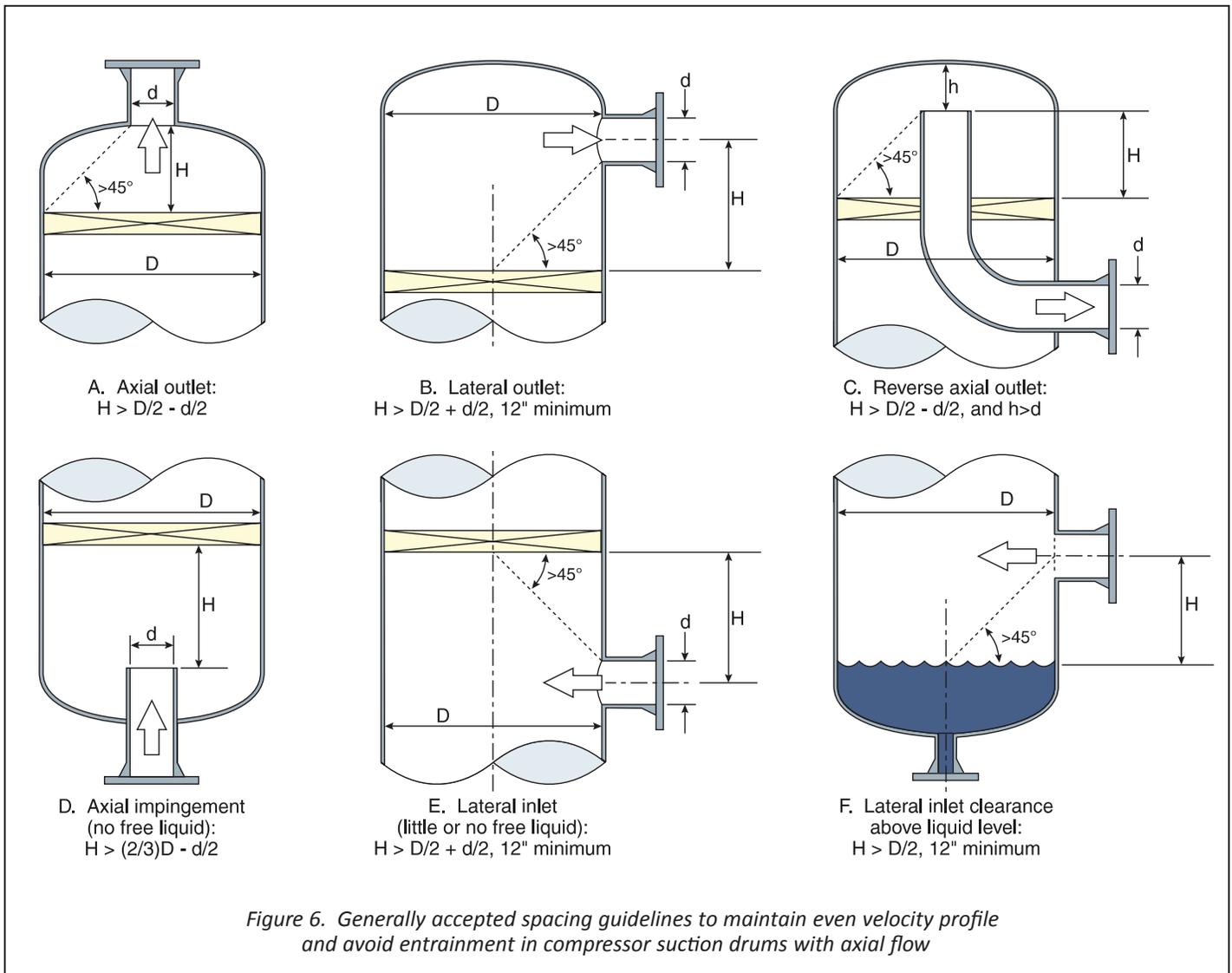


Figure 6. Generally accepted spacing guidelines to maintain even velocity profile and avoid entrainment in compressor suction drums with axial flow

liquid re-entrainment and low velocities with poor efficiency as shown in Figure 7.

In an existing conventional drum where the mist eliminator is too close to the gas outlet, there may not be enough room to lower the mist eliminator. The solution then might be a properly designed flow distribution device located above the mist eliminator to create a more uniform velocity profile.

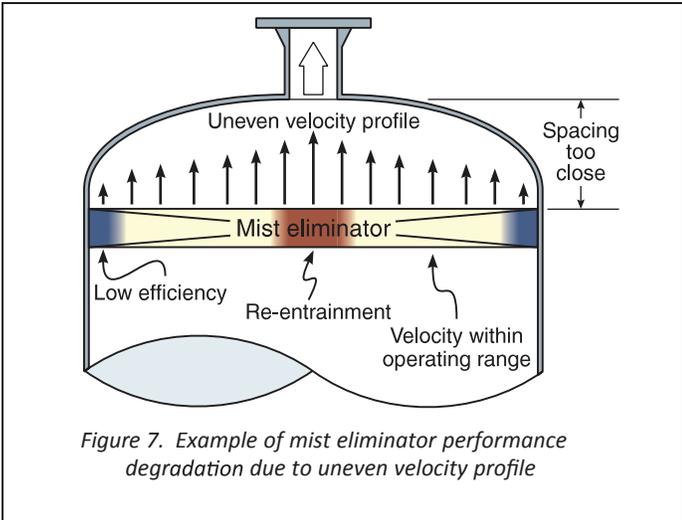


Figure 7. Example of mist eliminator performance degradation due to uneven velocity profile

Overcoming pressure-drop constraints

Processes that operate under vacuum or very low pressure immediately upstream of the compressor can be very tricky for suction drum design, because the pressure drop across the mist eliminator must be kept low. However, generally speaking, the lower the pressure-drop characteristics of a mist eliminator type, the lower its efficiency in removing mist. Liquid carryover from the suction drum may be a result of selecting a low-efficiency mist eliminator for the sake of low pressure drop.

When high efficiency is not required, a vane unit or low-density mesh pad may be recommended to achieve low pressure drop. To gain higher efficiency without much cost in terms of pressure drop, a possible solution is a dual-density mesh pad. In such a pad, the downstream layer has higher density than the upstream layer. The result is higher separation efficiency with only slight increase in pressure drop.

Throughput exceeding design capacity

In designing compressor knockout drums, like other gas-liquid separator vessels, conventional mist eliminators are generally selected and sized with a margin of about 10% above the design throughput. Flow rates beyond the upper operating limit may allow liquid carryover due to high velocities that cause re-entrainment from the mist eliminator element.

More specifically, mist eliminators are typically sized for cross-sectional area to achieve a design velocity according to the Souders-Brown vapor load factor K:

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

V_G = Gas velocity (volume flow divided by cross-section)

ρ_L = Liquid density

ρ_G = Gas density

Conventional horizontal mesh pads are traditionally sized for a K factor of 0.35 feet per second, which corresponds to a velocity of 10 feet per second in the reference case of water and air at room conditions.

When a knockout drum's throughput has grown to exceed its capacity, there are generally two options:

1. Replace the vessel with a larger one to allow a mist eliminator with greater cross-sectional area, thus reducing the velocity.
2. Replace the mist eliminator in the existing vessel with one using the latest technology to maintain efficiency with higher throughput.

Option 2 is generally much more cost-effective and often does not require prohibitive down time. In a traditional vertical cylindrical vessel, the traditional horizontal orientation is no longer the only solution. Compressor knockout drums can be retrofitted for capacity increases using any of the following techniques:

1. Vertical mist eliminator elements with horizontal flow (K = 0.42 for mesh pads, K = 0.65 for vane units)
2. Properly engineered baffling for even velocity profiles with close spacing
3. Horizontal mesh pads with drainage layers or multiple zones that can increase capacity by 10 to 12% (K = 0.40)
4. Amisco Double-Pocket Vanes that can double the capacity of a conventional vane unit (K = 0.8 to 1.1)
5. Mesh-vane combinations that can increase efficiency and capacity by 10% to 25% (K = 0.5 to 0.65)
6. Mesh agglomerator followed by Double-Pocket Vanes for highest efficiency (99.9% of 2-micron droplets) and greatest capacity increase
7. Two-bank or four-bank configurations that allow mist eliminator elements of greater cross-sectional areas

Figure 8 illustrates several of these possibilities: horizontal flow through vertical mist eliminator elements, use of mesh pads to agglomerate fine mist into large droplets that are removed by vane units, and a double-bank configuration. Amisco's design specialists can help apply such advanced means of optimizing the efficiency and capacity of existing knockout drums to create optimal solutions for particular applications.

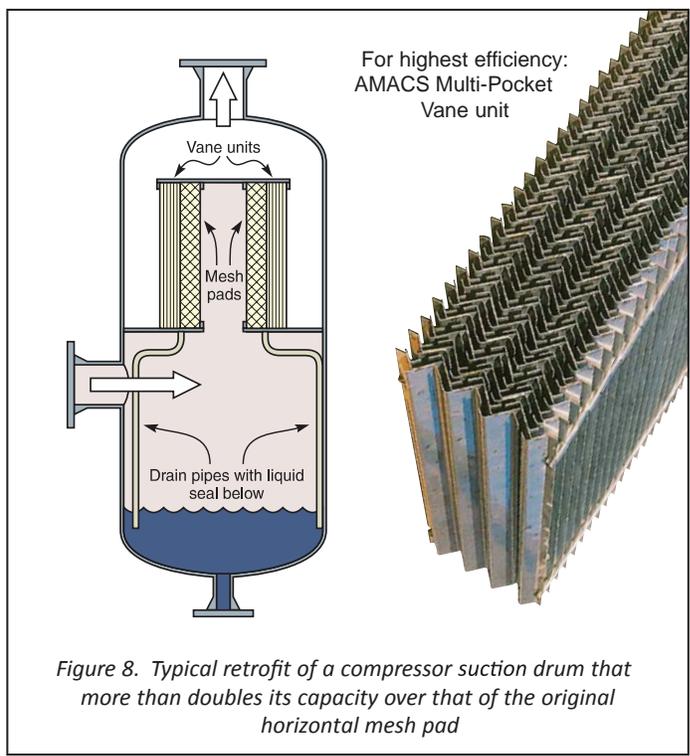


Figure 8. Typical retrofit of a compressor suction drum that more than doubles its capacity over that of the original horizontal mesh pad

Retrofit without recertifying for ASME code

Retrofitting an existing vessel for any of the foregoing suggested remedies has one drawback: it often requires welding new support rings, beams, clips and other structures to the vessel wall. Most vessels are ASME code certified. Thus, after welding to the vessel wall, the welded area must be heat-treated, and the vessel must be recertified. It is generally desirable to avoid this cumbersome procedure. AMACS offers expansion rings that are made in sections that can be passed through a manway. (See Figure 9.)

The rings are then bolted together and wedged against the vessel wall without welding. The unique double expansion design ensures that the installed ring does not move during operation. Once the rings are installed - either in vertical or horizontal vessels - beams can be bolted to the rings and complete housings can be built up inside the vessel.

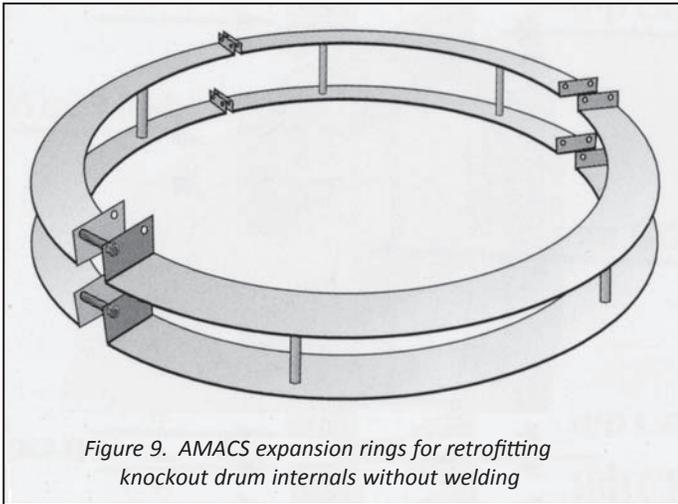


Figure 9. AMACS expansion rings for retrofitting knockout drum internals without welding

Using inlet diffusers to relieve carryover

Inlet design is one of the most commonly neglected aspects of a compressor knockout drum design, thus often the cause of poor performance. In the example shown in Figure 10; a half-pipe inlet deflector projecting into the vessel reduces the gas flow area of that position, with the following results:

1. Gas jets to the back wall of the vessel.
2. Without enough space to diffuse the jet, gas utilizes only part of the mist eliminator. Due to uneven velocity profile, liquid carryover occurs as in Figure 7.
3. The gas jet agitates the accumulated liquid below, generating droplets.
4. Turbulence spoils normal gravity settling of larger liquid droplets below the mist eliminator. Additional liquid load increases the likelihood of flooding the mist eliminator.

A properly selected inlet diffuser added to an existing knockout drum (Figure 11) provides more effective separation of liquid coming in with the gas and distributes the gas evenly throughout the vessel diameter before the gas moves upwards.

Damage by sudden pressure changes

Carefully review the transient pressures that occur at the knockout drum and mist eliminator during all phases of operations. The suction drum could see a sudden surge of flow in either direction due to compressor recycle or opening an anti-

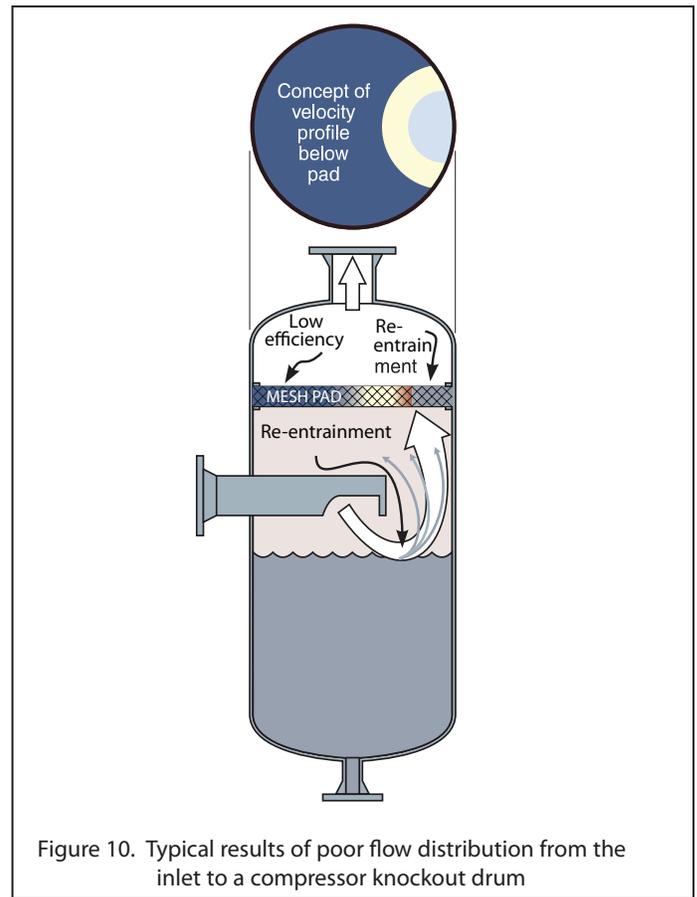


Figure 10. Typical results of poor flow distribution from the inlet to a compressor knockout drum

surge valve. Thus, a mesh-type mist eliminator can be subjected to forces not seen in normal operation. This can dislodge the pad sections, leading to compressor damage from liquid carryover or even from fragments of the pad.

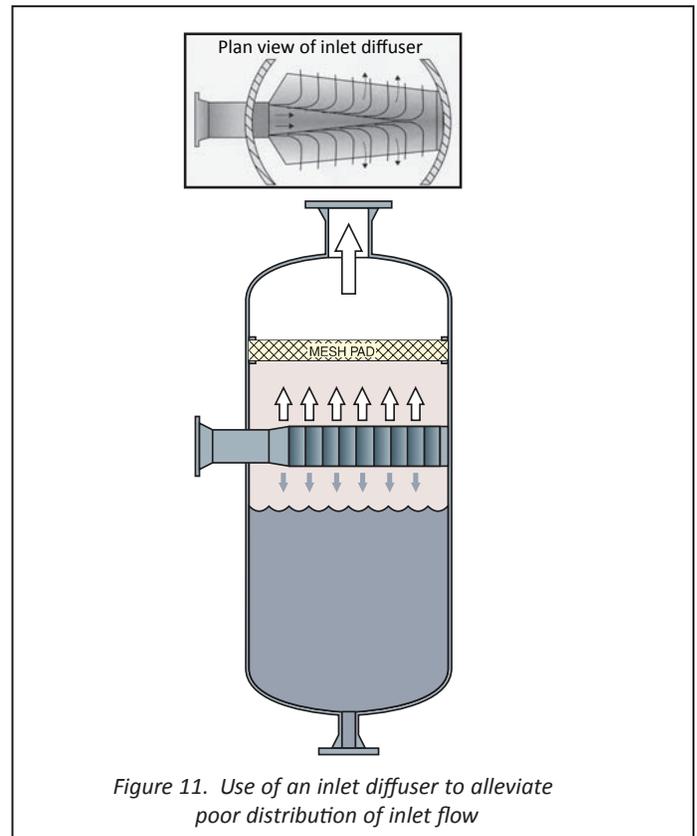


Figure 11. Use of an inlet diffuser to alleviate poor distribution of inlet flow

Pads and vanes can also be damaged by freezing liquids in cold climates. In natural gas production and pipelining, hydrate formation is known to destroy mesh pads and vanes.

To cope with any of these scenarios, as shown in Figure 12, any or all of the following remedies can be applied to mist eliminator elements:

1. Reinforce with heavy-duty material.
2. Fasten with bolts instead of traditional tie wires, or provide an upper support ring in addition to the lower one.
4. Provide a pressure relief door in the case of mesh.

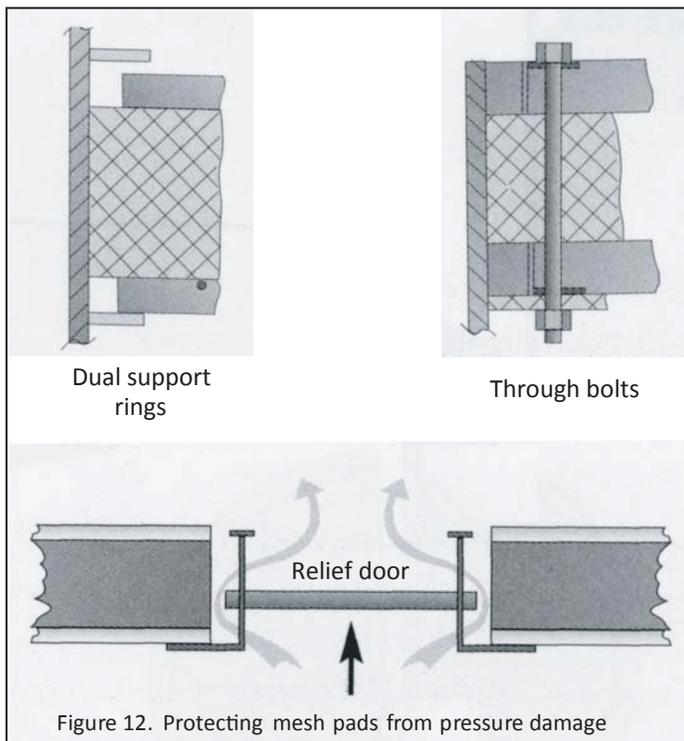


Figure 12. Protecting mesh pads from pressure damage

Compressor knockout drum cases

Ethylene plant debottleneck

A large ethylene producer needed to debottleneck its six-stage compressor train to increase throughput. This project needed to be accomplished with minimal cost and down time.

Using conventional mist eliminators - mesh pads or horizontal-flow vanes - the knockout drum before each compressor stage would have to be enlarged. For instance, the drum at the inlet to the first stage, eight feet in diameter, would be replaced by a 14-foot vessel.

After thoroughly reviewing the process conditions and internal geometry of each knockout drum. We then customized each existing drum with double-pocket vanes and mesh agglomerators arranged as in Figure 8, using on e two or four banks as required. To ensure proper gas distribution, we added inlet diffusers as in Figure 11 and flow distribution plates on the downstream side of the vane units. The result was 35% increased capacity while achieving an efficiency of 99.9% of 1-micron and larger mist droplets.

Fertilizer plant capacity boost & amine loss cut

A 4-train fertilizer plant needed more ammonia gas processing capacity in one of the trains to increase production capacity. The bottleneck was the overhead knockout drum in two of four carbon dioxide absorber towers in that train. Those vessels also served as suction drums for the compressors that followed. In addition, it was desired to reduce excessive loss of valuable amine in the form of mist escaping the knockout drums.

On reviewing the absorber process conditions it was discovered that the available space in one of the drums was very tight, we were able to solve this problem by retrofitting both drums with a double-bank system as in Figure 8. In each bank, a mesh agglomerator is followed by an AMACS Multi-Pocket Vane unit. The result was a 30% capacity increase. In addition, the rate of amine loss fell to 0.05 gallon per million standard cubic feet, which corresponds to savings on the order of \$75,000 per year. Another benefit was elimination of a cause of pitting corrosion in the compressors.

Gas production & condensate recovery increase

A large oil and gas company wanted to revamp several dozen of their 30-year-old two-phase field separators (sizes 2 to 5 feet OD). The purpose was to increase capacity and improve recovery of condensate. As in the preceding case, the separators were also suction drums for compressors.

As part of a joint venture with a local fabrication shop, we moved the units from the field removed the old internals, enlarged the inlet and outlet nozzles, and retrofitted the vessels with Multi-Pocket Vane units. The separators were ASME-code recertified painted, and reinstalled in the field with new instrumentation. This rejuvenation saved the company thousands of dollars per unit as compared to purchasing new separators. Gas capacity increased by up to 50%, and condensate recovery went up by many thousands of barrels per year.

THESE CASES are typical of many applications where our separation technology has made a big difference. Similar results can be achieved for a wide variety of compressor knockout drums in refineries, gas plants, oil and gas exploration and production, and petrochemical plants.



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