SEPCO PROCESS, INC.

Mist Eliminator Design Manual

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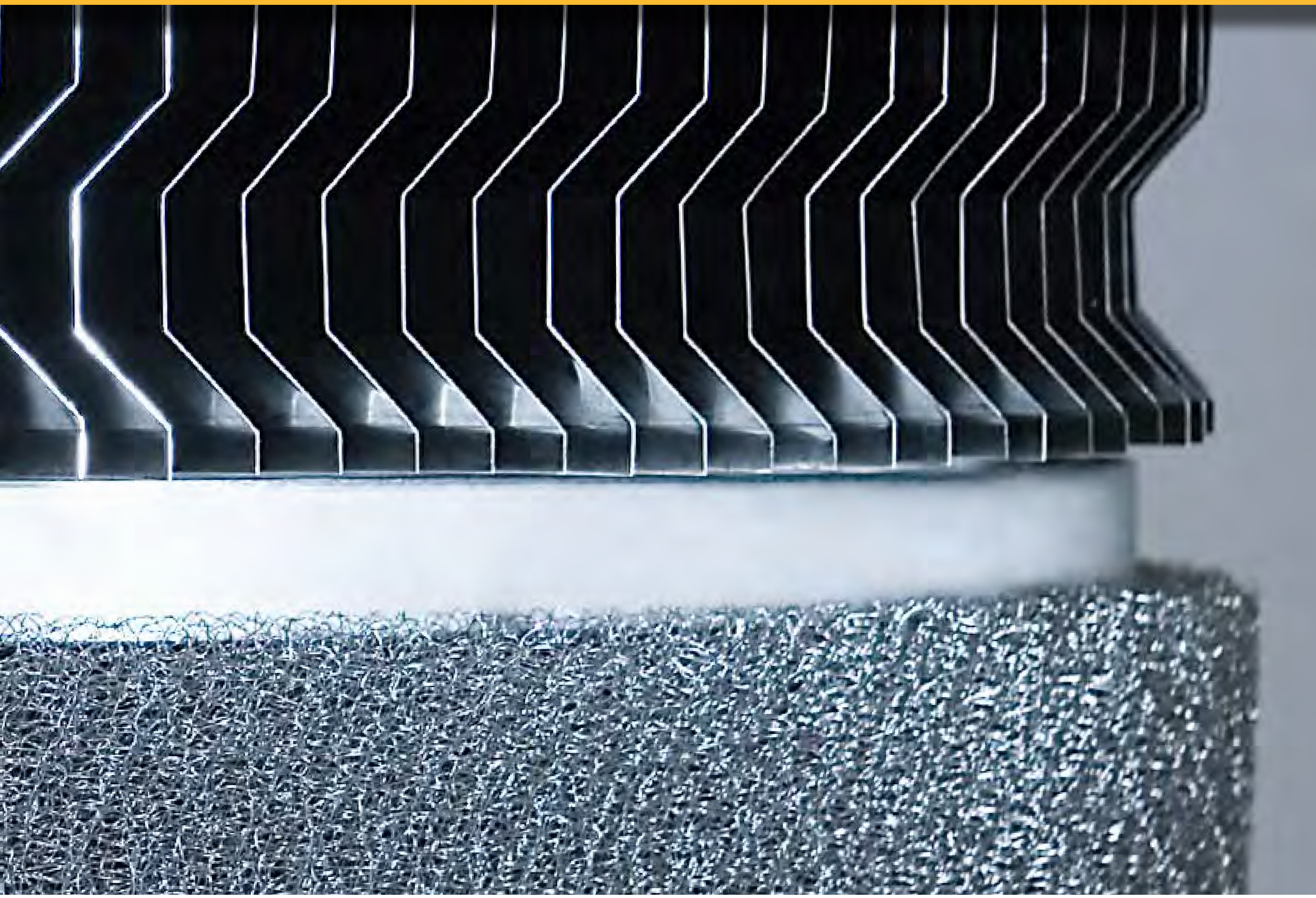


HIGH-PERFORMANCE SOLUTIONS TO YOUR MIST ELIMINATION NEEDS

Since its inception SEPCO PROCESS,INC. has been gaining a global reputation for responsive and reliable process equipment solutions that meet customer needs both technically and commercially. Based in Houston, Texas, home to the world's largest concentration of Oil, Gas, and Chemical operating companies, as well as the engineering and manufacturing companies that support them, Sepco Process provides advanced design solutions and premier products on-demand to a wide range of process applications. While production is focused on the fabrication of the most common types of mist eliminators - mesh pads and vane baffles - service is the corporate motto from the CAD Designer to the Installation Supervisor and back to Technical Sales who follow up, assuring themselves that all the client's expectations have been met or exceeded. Presented in this brochure are the basics of the entrainment separation strategies that SEPCO PROCESS, INC. uses to keep your plant at the peak of performance.

DUTY

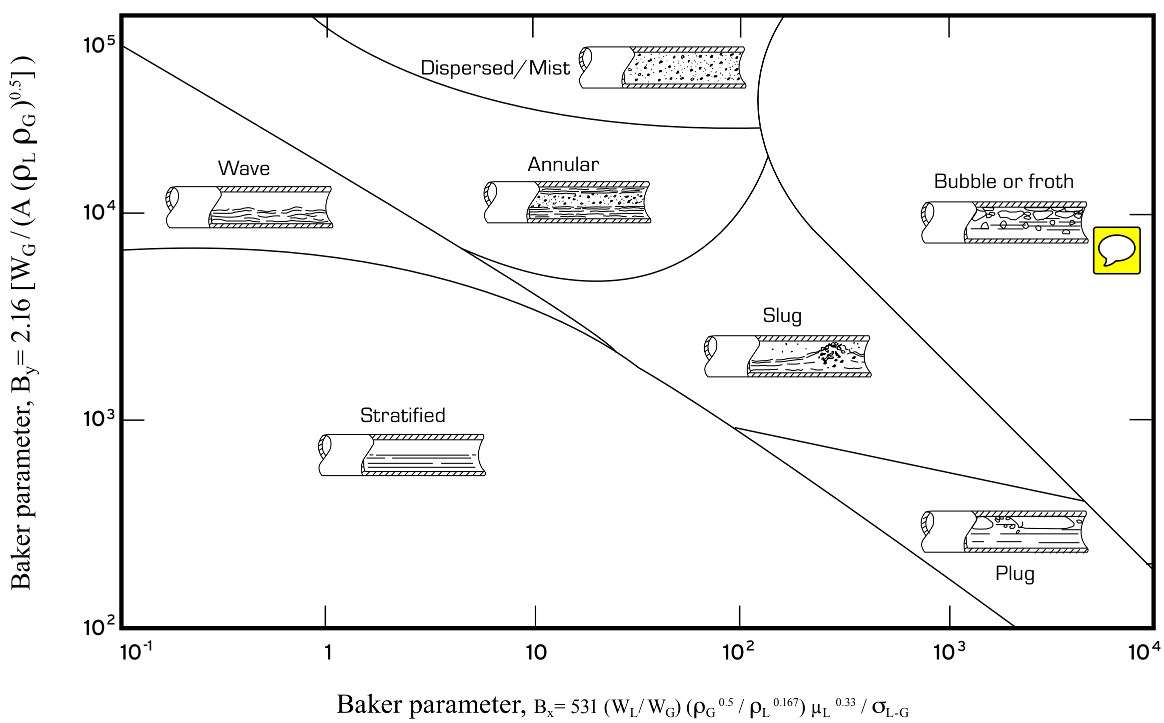
Mist eliminators are most commonly found either in vertical towers or in 2- or 3- phase separator drums which can be either in the vertical or horizontal orientation. This equipment can also be new-build or existing. Once a customer has decided that a technical solution is necessary due to performance or maintenance issues, each application is reviewed in detail by SEPCO PROCESS, INC. from both the process and mechanical points of view. The project then becomes a custom designed and built installation that makes the most of the client's investment in this critical capital equipment expenditure.

SLUGS, MISTS, OR FOGS?

The first consideration in a mist elimination application is the characterization of the entrained droplets or slugs that need to be handled. Figure 1 shows what is known as a Baker Chart which can be used to determine in which regime the gas and liquid phases of an inlet stream to a separator are located. Mesh pads in particular are designed for challenge streams in what is shown as the dispersed/mist regime. This analysis is, therefore, crucial in determining the necessity of an inlet device to perform the separation of the bulk liquid phase and often break the momentum of the wet inlet stream so that even finer droplets are not created.

Most engineering texts indicate that the mist in a dispersed regime will develop into a Gaussian shaped droplet size distribution after approximately ten diameters of straight pipe. The peak will be skewed to the left at runs less than that and to the right when the runs are long. In pipe runs between equipment in a chemical plant, refineries, or in well-stream piping in oil and gas production, droplet formation is the result of the turbulent effects of the mixing of the gas and liquid phases. This will yield mean diameters in the 100 to 200 micron range depending on the velocities of the phases, the liquid–gas interfacial (surface) tension, and the viscosity of both phases. If condensation takes place due to inadequate pipe and equipment insulation or due to residual cooling downstream of heat exchangers, then the means can be an order of magnitude lower at 10 to 20 microns. Often the droplet distributions in the inlet to a separator are bi-modal (having two peaks).

FIGURE 1 **BAKER CHART FOR FLOW-REGIME PREDICTION**



When packed towers are operated in counter-current gas-liquid flow, droplets are formed by the rising gas stream shearing them off the thin films formed on the packing surface. Inadequate vapor distribution accentuates this effect. Also, when single-phase spray nozzle headers are used for liquid distribution there will be significant back mixing of fine droplets at the top of the tower. Lastly, compromised liquid distributors are known to create sprays from holes in their walls, as well as from missing drip tubes and riser covers.

Entrainment from a tray depends on the regime existing above its floor. Reference 7 reports that droplets formed by bursting bubbles are primarily <200 microns, while the jetting in a dispersed regime creates large quantities of droplets >1000 microns. Predictive methods for the quantity of entrainment created are documented there. They show that this rises dramatically near the flood point and, therefore, for proper performance this situation is minimized during the design phase by manipulating the active vs. downcomer area, cap or valve size and design, weir height, etc. Trays have the advantage, though, in that they typically have enough back pressure to evenly distribute the flow by themselves.

INLET DISTRIBUTORS/DIFFUSERS

Since nearly all mesh and vane mist eliminators flood at <2" (50 mm) water column (WC), there is a minimal back pressure effect. Therefore, any incoming maldistribution will be found on the outgoing side. In this regard a carefully selected feed distributor provides three benefits:

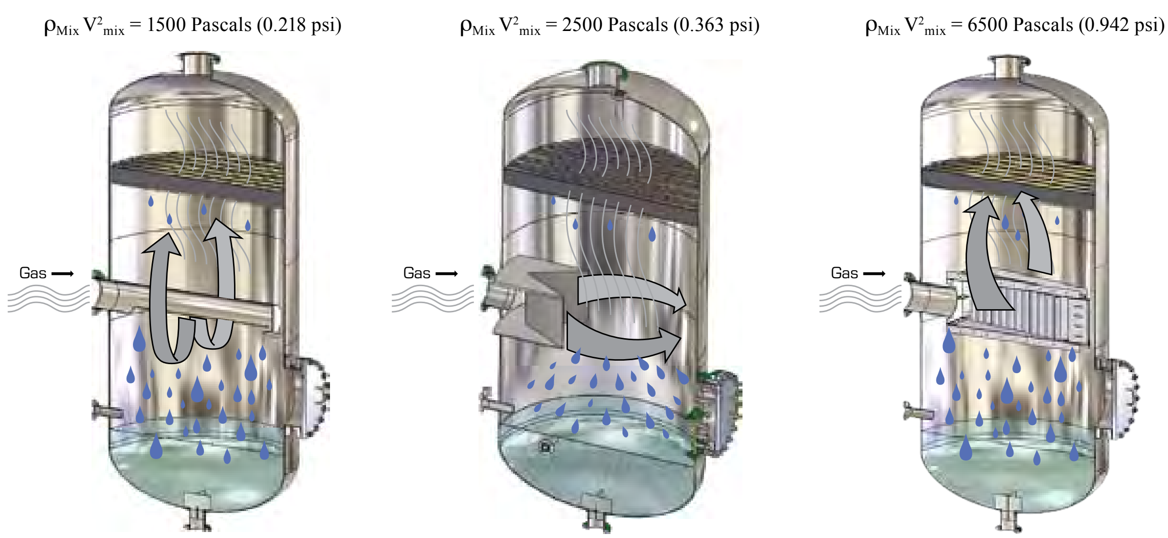
1. Removing the bulk liquids so that only mist droplets impinge on the separation internals
2. Evening out the flow to across the cross section of the tower or drum and
3. Deflecting the incoming momentum so that shattering of the entrained droplets is minimized

SEPCO PROCESS, INC. has three types; the Sepco's Pipe (SP), the Sepcos' Wedge (SW), and the Sepco's Vane Inlet Diffuser(SVID). Selection of the appropriate device is dependent on the momentum of the incoming feed (see Figure 2). These devices allow fine liquid droplets alone to challenge the mist eliminator element. At the same time they smooth out the flow which gives these devices extra, hidden capacity.

WHICH TYPE OF MIST ELIMINATOR SHOULD YOU CHOOSE?

Deciding on the selection of the optimum mist eliminator for any given application is as challenging as with any process equipment because a balance must be made amongst a whole matrix of often conflicting requirements and equipment options. The design requirements include capacity for gas flow, capacity for liquid flow, mist removal efficiency, pressure drop (or energy expenditure), and equipment life. The latter is a catch-all for resistance to corrosion, erosion, and fouling by solid particulate, waxes, and/or pastes. The internals to be discussed here are mesh, vanes, demisting cyclones, and filters. Vanes can have single or double pockets, or none. Demisting cyclones can be either axial or tangential flow types. Sepco Process, Inc. currently supplies a complete line of

FIGURE 2

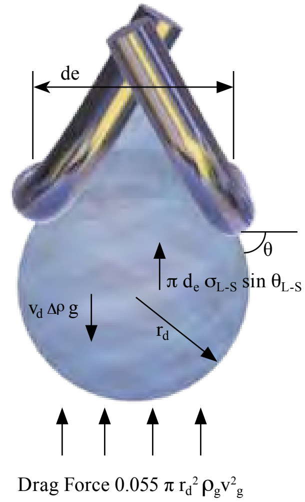


ρ_{mix} = Density of Mixture V_{mix} = Velocity of Mixture mesh pad, vane mist eliminators and demisting cyclones. Fiber beds, membranes and electrostatic precipitators are common when light loadings of ultra-fine droplets (majority less than one or two microns) are encountered, but these are are not currently offered by Sepco Process, Inc.

Another consideration at the front end of a design is whether to install the internals in the vertical or the horizontal. Axial-flow cyclones and filters are generally insensitive to orientation. However, the countercurrent flow of ascending vapor and descending collected liquid limits the gas handling capacity of horizontal mesh pads and vanes without double pockets (see Figure 2). In co-current horizontal flow, when the internals are in the vertical and their section height is minimized to less than five feet (1.5 meters) with intermediate collection troughs, pooling of the liquid phase at the bottom of the element is avoided. Also, collected droplets can be shielded to a large extent from shearing by the crosscurrent vapor flow in the case of single pocket vanes, while it is almost total in double pocklet vanes. This allows dramatically larger gas handling capacities which in turn results in increased efficiencies because the higher allowable velocities simultaneously increase the effects of inertia. The drawback with horizontal flow is that housings are always required to frame the internals from vapor bypass and to provide a liquid collection sump that has downcomer pipes installed to direct the collected mist to below the vessel's lowest liquid level. Also, in order to effect an even flow to the element's upstream face, baffling becomes much more complex, while a vapor distributor is also typically needed on the downstream face (see figure 4 on page 7).

In the vast majority of applications in the Hydrocarbon Process Industries (HPI), up and downstream, as well as the Chemical Processing Industry (CPI) essentially all mist droplets are larger than 1 to 2 microns (inorganic acid production, where gas-phase reactions can take place, is one exception). This is the area where SEPCO PROCESS, INC. Mesh and Vane Mist Eliminators, along with synergistic combinations of the two, find their role due to high efficiency, low energy consumption, and low capital cost. The efficiency of most all-metal or all-plastic mesh pads drops off considerably below 5 microns. A common technique to capture droplets one micron and above is to use a mesh pad to coalesce fine droplets into ones large enough to then be handled by a downstream vane (or axiflow demisting cyclone). This can be done with the elements in either the vertical or the horizontal (see front and back cover), for horizontal and vertical flow, respectively. Although the mesh pad is intentionally

FIGURE 3



operated here in a flooded condition, the higher capacity vane is not. The result is the combination of the high efficiency of the mesh pad and the high capacity of the vane or demisting cyclone. Indeed, due to the increased inertia of the droplets at their higher velocities, the combinations in many cases now can achieve removal of ≥99+% of 2 micron droplets.

The key factor when designing a high-capacity mist eliminator is to be assured that operation is a safe distance away from the point of re-entrainment. Making this determination is complex, with reliable designs being a combination of science and practical experience. Traditionally, the separation process has been divided into three steps. It starts with the force of the flow of the vapor dragging the mist droplets into a wire or a vane blade collector. Next, several droplets must adhere to these surfaces to give them the opportunity to coalesce into larger droplets. This finally allows 0.5 millimeter (0.02 inch) or larger droplets to disengage by gravity from the flowing vapor stream in standard capacity mist eliminators at the downstream and under sides of the element in horizontal flow, or the upstream face in vertical flow.

The force balance on a droplet can be represented by the following equation and is shown in Figure 3.

Drag Force	+	Adhesive Force	↔	Gravity Force
$0.055\ \pi\ r_d^2\ \rho_g\ v_g^2$	+	$\pi\ d_e\ \sigma_{L\text{-}S}\ \sin\theta_{L\text{-}S}$	↔	$V_d\ \Delta\rho\ g$

A dynamic balance is set up in these mist eliminators where the inertial forces combine with adhesive forces until gravity can take over and complete the separation. Mesh-vane combinations can have the mesh in the pre-conditioning or collecting position. Generally having mesh in the pre-conditioning or coalescing position allows for overall higher separation efficiencies, while having it in the final collector position allows the combination to have higher liquid handling capacity and fouling resistance.

Due to their ≥98+% voids, all horizontal orientation metal mesh pads will drain liquid loads of upto one gpm/ft^2 (2.4 m^3/m^2-hr) even when flooded under the higher allowable gas loadings of a horizontal vane mist eliminator without pockets. When the mesh pad coalescer and a high-capacity vane (double pocket) or axi-flow demisting cyclone collector are in the horizontal, the mist now with a larger droplet size distribution, is carried by the strong drag force of the high velocity gas phase into the collector element and ultimately drains down into the column sump via a series of downcomer pipes. Care must be taken, however, to avoid an intermediate loading zone. This is characterized by a build-up of the liquid phase in the mesh pad or between the mesh and collector elements. This unstable balance of forces on the droplets can lead to surging. If this situation cannot be avoided during the life cycle of the drum or tower, then either turn the mist eliminator elements into the vertical or delay the installation of the mesh pad until flow of the process stream is in excess of the intermediate zone.

MIST ELIMINATION – A SYSTEMS APPROACH

The ideal situation is to incorporate an appropriate inlet device (ID) in the mist elimination system as well. Sepco Process, Inc. uses the following designations for ID's in tandem with mist elimina-tors with M standing for Mesh or V for Vane. When fouling is suspected or already evident a well-designed header of spray nozzles can add months, if not years, to the on-stream life of a mist eliminator system. They can be used while on-line when pointed to the upstream face of the element or even the downstream face of the first of two or more stages of mist eliminators. Consult SEPCO PROCESS, INC. on our in-novative retro-fit mist elimination and spray systems.

Mist elimination equipment is a requirement in both the up and downstream ends of the oil and gas industry. Due to the high pressures developed in underground reservoirs that can be thousands of feet below sea level, relatively high pressure drop mist elimination devices, such as demisting cyclones and filters come into consideration. In refineries and chemical plants, on the other hand, where operating pressures are typically atmospheric to a few atmospheres, mesh pads and vanes predominate.

TABLE 1 COMPARISON OF THE PERFORMANCE OF VARIOUS MIST ELIMINATORS

English Units	KO Drum with SP or SW Only		Horizontal Mesh Pads**			Horizontal Metal Vanes		Vertical Metal Vanes			Horizontal SHMV[1] (metal)	Vertical SHMDP[3] (metal)	Reverse Flow Cyclones	SHM w/ Axial Cyclones	Two Stage Filter Separator
	Vertical	Horizontal	Metal	Plastic	Co-Knit w/Yarn	No Pocket[1]	Double Pocket[3]	No[1]	Single[2]	Double Pocket[3]					
Allowable K-Factor, ft/s*	0.18	0.22	0.35	0.28	0.22	0.50	0.85	0.65	0.65	0.85	0.50	0.85	1.0[3]	1.3[3]	0.65
Allowable L, $ft^3/hr\text{-}ft^2$ *	200	200	22	8	0.7	40	8	40	80	8	200	40	200[4]	200	40
Turndown Ratio, Gas ϕ	∞	∞	3.3	3.3	∞	2.5	2.5	2.5	2.5	2.5	4.8	5	3	5	3
D_{98}, microns	150	100	5	4	2	12	8	10	10	8	2	2	20	10	1
Tolerance to Slugs	High	V. High	Med	Low	V. Low	High	Med	Med	High	Med	V. High	V. High	V. Low	V. High	Low
Tolerance to Sand	High	High	Low[5]	V. Low	V. Low	Med[5]	Not Recommended	Med[5]	Low[5]	V. Low	Med[5]	Med[5]	High	High	V. Low
Tolerance to Sticky Material	High	High	V. Low	Low[5]	V. Low	Med[5]	Not Recommended	Med[5]	Low[5]	V. Low	Med[5]	Med[5]	High	Low	V. Low
Typical DP, inches WC	Nil	Nil	1	1.5	2	0.5	2.5	0.5	1	2	2	7	10 PSID	<2 PSID	10 PSID

* Multiply by 0.3048 to convert to m/s and $m^3/hr\text{-}m^2$ ** Consult Sepco Process, Inc. on vertical mesh pads for horizontal flow [minimum 12 inch (300 mm) thick]

1 Triple hump vane in Figures 5 and 6

2 See Figure 7

3 Based on an upstream application where ρ_g = 2.0 lb/ft^3 & μ_g=0.015 cP; ρ_l = 60 lb/ft^3 & μ_l=1.0 cP

4 Based on the entire tower cross sectional area for reverse flow cyclones meaning they have more liquid handling capacity than axial cyclones whose effective area is net of their housing.

5 Consider adding a Sepco Process, Inc. Spray System

Table 1 gives the relative characteristics of a wide variety of commonly available entrainment separation devices that will allow engineers to select the type(s) that can be used to process their mist-laden stream and to begin to strategize the development of a successful solution. These correlation factors are used above:

Vapor Capacity in ft/s (m/s):	$K = v_g [\rho_g/(\rho_l-\rho_g)]^{0.5}$ (Souders-Brown Equation)
Liquid Capacity in ft³/hr-ft² (m³/hr-m²)	$L = Q/A$
Flow Parameter, dimensionless	$F.P. = Q_l/Q_g[\rho_l/\rho_g]^{0.5}$

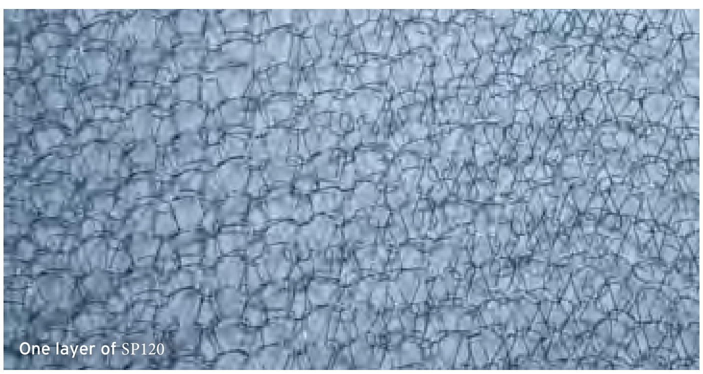
In Table 1 it is assumed that the equipment has been properly installed, that its surfaces are clean, and that liquid loadings are below the maximums shown. The gas and liquid capacities shown are based on the superficial velocity in the entire tower column cross section in vertical flow or the effective area of vanes or Axial demisting cyclone assemblies net of the housing in horizontal flow. SVID Inlet Devices are assumed to remove 80% of the inlet liquid in the mist or froth regimes (SW Inlet Devices remove approximately 65%) with virtually no pressure drop. Pressure drops are net of those across the vessel's inlet and outlet nozzles.

Mesh pads are 6 inch (15.2 cm) thick in all cases. For mesh and vanes it is further assumed that droplet surface tensions are greater than 15 dynes/cm and operating pressures are less than 1450 PSIG (100 barg). If these operating conditions do not exist, consult SEPCO PROCESS, INC..

The demisting cyclones in Table 1 are typically 2" to 4" (5 to 10 cm) in diameter by 18 to 20 inch (0.46 to 0.51 m) tall. Reverse flow demisting cyclones have tangential entry and are held between two tubesheets, while axi-flow demisting cyclones are mounted on decks alone or in boxes of 4 to 10, depending on the size and manufacturer. The filters in filter separators are typically 4 inch (10 cm) OD x 3 inch (7.5 cm) ID and 3 or 6 feet (0.9 or 1.8 m) long.

DESIGN FORMULAS FOR MESH PADS, VANES, & THEIR SYNERGISTIC COMBINATIONS

SEPCO PROCESS, INC.'s wide range of mesh and vane mist eliminators, alone or in combination, is used to solve even the most difficult problems in the CPI and HPI. The physical dimensions, correlation constants, formulas, and procedures given below for this equipment are detailed in both 'engineering' English and metric


One layer of SP120

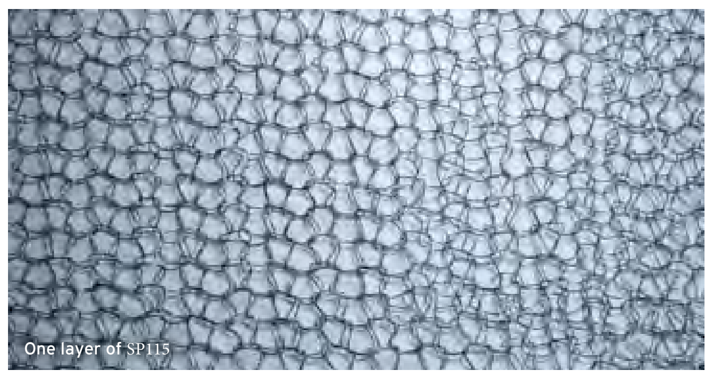

One layer of SP115

TABLE 2 MESH STYLE COMPARISON CHART

Style	Material	Nom. K-factor		Wire Diameter		Wire Density		Mesh Pad Density		Voids	Surface Area, a	
		ft/s	m/s	inches	microns	lb/ft³	kg/m³	lb/ft³	kg/m³	percent	ft²/ft³	m²/m³
SP180	Polypropylene	0.27	0.082	0.011	279	56	897	2.7	44	95.4	188	617
SP120	Stainless steel[1]	0.27	0.082	0.006	152	498[1]	7978[1]	7.2	117	98.5	115	378
SP200	Stainless steel[1]	0.27	0.082	0.006	152	498[1]	7978[1]	12.0	192	97.6	195	639
SP045	Stainless steel[1]	0.42	0.128	0.011	279	498[1]	7978[1]	5.0	80	99.0	45	148
SP065	Stainless steel[1]	0.39	0.119	0.011	279	498[1]	7978[1]	7.0	112	98.6	63	207
SP085	Stainless steel[1]	0.35	0.107	0.011	279	498[1]	7978[1]	9.0	145	98.2	85	300
SP115	Stainless steel[1]	0.35	0.107	0.011	279	498[1]	7978[1]	12.0	192	97.6	105	344

1 Metal mesh pad densities are based on 300 series stainless steel. SEPCO PROCESS, INC. can knit any metal that can be drawn into a fine wire. Percent voids, surface areas, and nominal K-Factors for the different styles stay the same when the same metal wire diameter is used.

units to enable fruitful collaboration between customer and supplier whenever desired. These tried-and-true approaches are well documented for their reliable, accurate, and cost-effective results.

SP085 Mesh Mist Eliminator

WIRE MESH MIST ELIMINATORS

The data for deriving the capacity and efficiency of SEPCO PROCESS, INC.'s single component knitted mesh pads is shown in Table 2, while that of co-knits of a mono-filament carrier wire and multi-filament yarn is shown in Table 3.The two-layered styles, SP4775,

SP4775, SP4485, SP41340, and SP14213; with 3 inches (7.6 cm) of single-component mesh below 3 inches (7.6 cm) of co-knit that are listed in Table 3 use the mono-filament layer to first remove the bulk of the entrainment. Then the intimate contact between the all-metal or all-plastic meshes is used to sponge the collected liquid phase out of the capillary passages in the multi-filament yarns where high efficiency removal of the remaining light loading droplets <10 microns is effected. As shown in Tables 3 and 4, this construc-tion increases capacity and fouling resistance, while decreasing pressure drop.

Capacity of a Mesh Pad

Two factors that affect the maximum allowable K-factor, and hence the capacity (in terms of the v_g in the Souders-Brown Equation above) for a mesh pad, are the viscosity of the collected liquid phase and the liquid loading on the upstream face. Multiply the K's in Tables 1 to 3 by the following factors to find K_{Design}. That is with μ_l in poise and L_{Mesh} in ft^3/ft^2-hr:

K_{Design} = $K \times F_\mu \times F_{LL}$

$F\mu$ = $(0.001/\mu l)^{0.2}$ when $\mu_l > 0.005$. When $\mu_l < 0.005$ then $F_\mu = 1$

F_{LL} = $1/(1 + 0.06\ L_{Mesh})$. When $4 < L_{Mesh} < 22$.

When $_{LMesh} < 4$ then $F_{LL} = 1$.

Consult SEPCO PROCESSwhen $L_{Mesh} > 22$.

Lmesh represents the liquid loading at the upstream face of the mesh pad.

One layer of SP485

TABLE 3 CO-KNIT MESH STYLE COMPARISON CHART

Style[1]	Material	Nom. K-factor[4]		Filament Diam.		Filament Dens.		Mesh Pad Density		Voids	Surface Area	
		ft/s	m/s	inches	microns	lbs/ft³	kg/m³	lb/ft³	kg/m³	percent	ft²/ft³	m²/m³
SP388	SS/Polyester	0.25	0.076	9.5E-04	24.1	86	1380	6.0	96	98.6	388	1271
SP775	SS/Polyester	0.21	0.064	9.5E-04	24.1	86	1380	12.0	192	97.2	775	2542
SP4775[2]	SS/Polyester	0.29	0.088	9.5E-04	24.1	86	1380	12.0	192	97.6/97.2	115/750	378/2542
SP242	SS/PTFE	0.25	0.076	8.3E-04	21.1	134	2150	6.0	96	98.5	242	795
SP485	SS/PTFE	0.21	0.064	8.3E-04	21.1	134	2150	12.0	192	97.1	485	1590
SP4485[2]	SS/PTFE	0.30	0.091	8.3E-04	21.1	134	2150	12.0	192	97.6/97.1	115/485	378/1590
SP670	SS/Fiberglass	0.23	0.070	3.5E-04	8.9	155	2480	6.0	96	98.5	670	2200
SP1340	SS/Fiberglass	0.19	0.058	3.5E-04	8.9	155	2480	12.0	192	97.0	1340	4400
SP41340[2]	SS/Fiberglass	0.28	0.085	3.5E-04	8.9	155	2480	12.0	192	97.6/97.0	115/1340	378/4400
SP1421	PP/Polypro Yarn	0.21	0.064	11E-04	28	56	897	4.0	64	92.8	1421	4662
SP14213[3]	PP/Polypro Yarn	0.27	0.082	11E-04	28	56	897	3.0/4.0	48/64	95.4/92.8	188/1421	617/4662

[1] All co-knits contain a single strand of multi-filament yarn in parallel with a 0.011 inch (0.028 mm) wire
[2] 3 inch layer of all 12 lb/ft³ (192 kg/m³) metal mesh Style SP115 below 3 inch layer of 12 lb/ft³ (192 kg/m³) co-knit mesh. D_{98} = 3 microns. [3] 3 inch layer of all 3 lb/ft³ (48 kg/m³) polypropylene mesh Style SPP3 below 3 inch layer of 4 lb/ft³ (64 kg/m³) co-knit mesh. D_{98} = 3 microns [4] When liquid load <1 ft³/hr-ft² (0.3 m³/hr-ft²)

When in the dispersed regime, a mist-laden stream operating at 150 PSIG (10.3 barg) or less typically challenges a mesh pad with an L_{Mesh} < 4. As vapor phase densities increases, so do liquid loadings per unit area. This causes the F_{LL} factor to come into effect as pressure increase which in turn causes the design mesh pad cross sectional areas to increase.

Pressure Drop across a Mesh Pad

The pressure drop across a mesh pad is a combination of the drag forces across both its high surface area, dry solid surfaces and across its in-situ hold-up of an adhering and fluidized liquid phase. Therefore it correlates to the equation below.

$$\Delta P_{Mesh} = (h/6) \times F_{DP} \times SG \times \rho_g v_g^2$$

ΔP is in inches of the entrained liquid phase (multiply by 2.54 for cm) and h is the thickness of the mesh pad or pad layer also in inches. The pressure drop correlation constants, F_{DP}, for both single component and co-knits constructions are shown in Table 4. This formula takes the dry pressure drop to be half of the overall. It is, therefore, conservative to take the pressure drop across several layers as being additive since the further downstream the mesh is in a pad, the drier it is.

Collection Efficiency of a Mesh Pad as a Function of Droplet Size

All the efficiency calculations given below take into account inertial impaction only. The highly efficient direct interception of fine droplets less than 5 microns in diameter by the ultra-fine fibers of our co-knit pads shown in Tables 1 and 3 is empirically known to occur when the operating parameters of both K < 0.22 ft/s (0.067 m/s) and L < 0.7 ft^3/ft^2-hr (0.2 m^3/m^2-hr) are in effect. These allow for the free gravity drainage of the collected and coalesced liquid droplets.

The percent collection efficiency of an all-metal or all-monofilament plastic mesh pad as a function of droplet diameter can be found as follows:

$$\eta_{Mesh}(d_d) = 100 \times \{1 - \exp[-2a\,H\,\eta_w / (3\pi)]\}$$

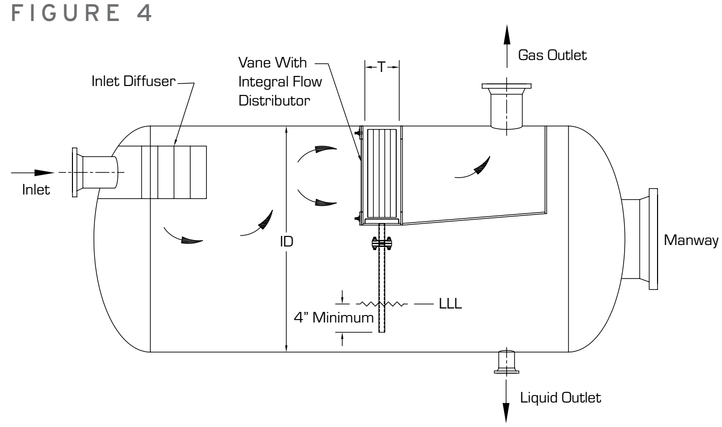
Where

a = Surface area of mesh pad, ft^2/ft^3 (see Table 2)

H = Depth of the mesh pad or layer, ft

η_w = Fractional collection efficiency of a wire (see below)

FIGURE 4



The fractional droplet collection efficiency for a wire or monofilament, η_w, in the equation above is a function of a dimensionless Separation Number, N_S, and the range of N_S in which the pad is operating. It is assumed here that D_d is greater than 0.000005 m (5 microns). See Table 2 for the diameter of target, D_w (multiply microns by 10^{-6} to convert to meters). The procedure for calculating η_w in **metric units** is as follows:

	N_S		=	$10 \times \rho_l \times D_d^2 \times v_g / (18 \times \mu_g \times D_w)$
If	$N_S < 0.15$	η_w	=	0
For	$0.15 < N_S < 2$	η_w	=	$0.2626 \ln(N_S) + 0.5578$
For	$2 < N_S < 10$	η_w	=	$0.1293 \ln(N_S) + 0.6432$
For	$10 < N_S < 30$	η_w	=	$-0.0001 (N_S)^2 + 0.006N_S + 0.88$
For	$30 < N_S < 50$	η_w	=	0.98
For	$N_S > 50$	η_w	=	0.99

TABLE 4 **PRESSURE DROP CORRELATION CONSTANTS, F_{DP}**

Metal Mesh		Polyester Co-Knit Mesh		Fiberglass Co-Knit Mesh		Fluoropolymer Co-Knit Mesh		Polypro Mesh	
Style	F_{DP}	Style	F_{DP}	Style	F_{DP}	Style	F_{DP}	Style	F_{DP}
SP200	0.513	SP775	0.894	SP1340	0.967	SP485	0.618	SPP3	0.422
SP120	0.314	SP388	0.539	SP670	0.677	SP242	0.476	SP1421	2.240
SP115	0.168	SP4775	0.716	SP41340	0.882	SP4485	0.547	SP14213	1.331
SP085	0.140								
SP065	0.110								
SP045	0.087								

VANE BAFFLE MIST ELIMINATORS

Capacity of a Vane

The articulated blade design, with a series of baffles at an angle to the vapor flow for droplet collection and in parallel for liquid film drainage, has been found both to increase capacity over those without parallel sections and also make the best use of the energy expenditure. The allowable K-Factors for the SEPCO PROCESS, INC. Vane Mist Eliminators are shown in Table 1. Due to their open structure, it is less necessary to make adjustments to a vane's capacity based on process parameters so long as the liquid loading, L, is below the values given in that table. The vanes without pockets are unaffected by liquid viscosities less than 20 cP. Capacities of single- and double-pocket vanes in the vertical orientation remain the same for viscosi-ties under 5 cP.


VS375 Vane Mist Eliminator

Pressure Drop across a Vane Baffle Mist Eliminator

The pressure drop across a vane mist eliminator follows the same formula as for mesh pads, only now since the height cannot change, the thickness is built into F_{DP} factors which are found in Table 5.

$$\Delta P_{Vane} = F_{DP} \times SG \times \rho_g v_g^2$$

Collection Efficiency of a Vane Baffle Mist Eliminator as a Function of Droplet Size

The terminal settling velocity of a droplet, v_t, is required in calculating the collection efficiency of a vane, η_{Vane}. The term v_t in turn is a function of a_c the acceleration due to centrifugal force and the drag coefficient, C_D. Droplets in the 3 to 100 micron range when present at the operating conditions typically encountered by a vane mist eliminator will settle according to Stokes Law. The drag coefficient in this range is directly proportional to the droplet Reynolds Number, Re_d, according to the formula $C_D = 24/Re_d$ where $Re_d = (d_d \times v_t \times \rho_g) / \mu_g$. Calculation of v_t is then simplified and can be represented by the second formula below, while the formula for the efficiency of a single vane baffle is shown in third formula following.

$$a_c = (2\, v_g^2 \sin\theta) / [w (\cos\theta)^3]$$

$$v_t = (d_d^2 \times \rho_l \times a_c) / (18\, \mu_g)$$

$$\eta_{Vane\ baffle\ i}(d_d) = 100\times\{1 - \exp[(-v_t \times w \times \theta) / (57.3\, v_g \times b \times \tan\theta)]\}$$

VS500

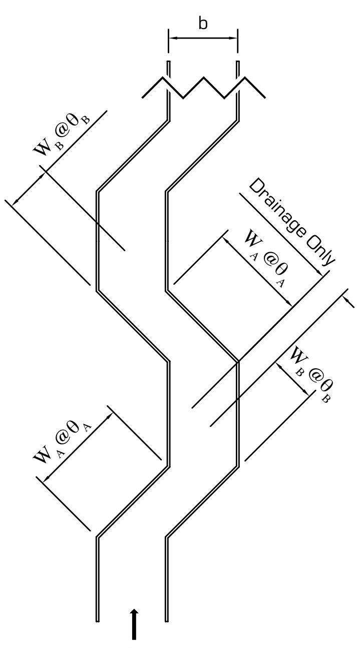


FIGURE 5 **PRESSURE DROPS FOR VARIOUS MIST ELIMINATORS**

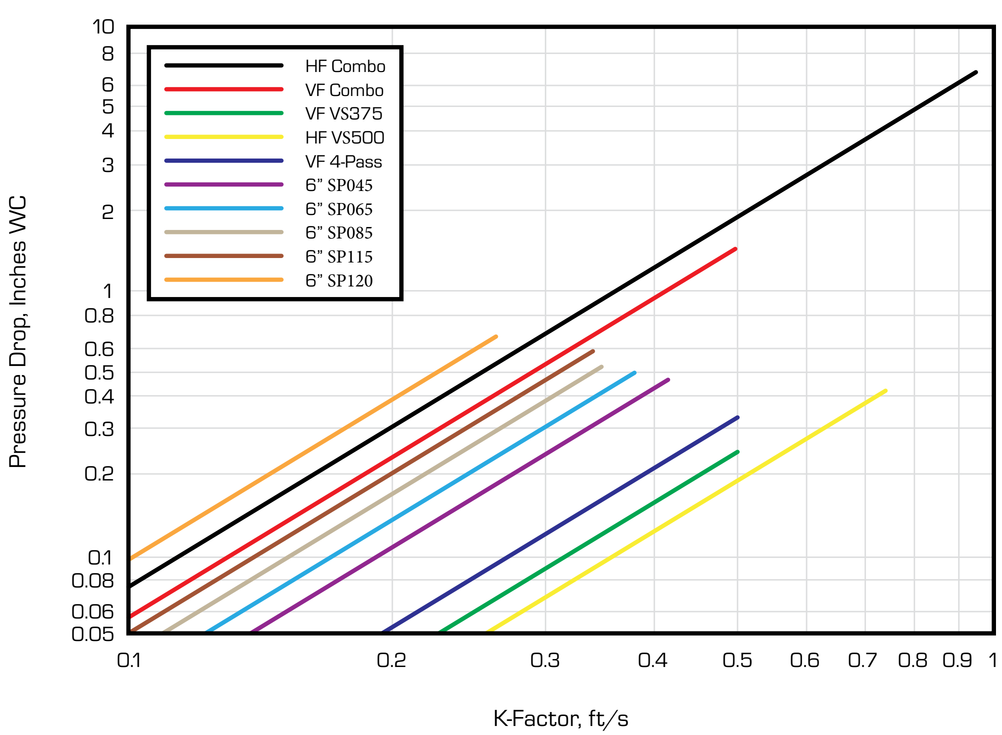


TABLE 5 GEOMETRIC AND CORRELATION CONSTANTS FOR VANES

			Baffle A			Baffle B			Baffle C			Height
Style	F_{DP}	b	w	θ	n	w	θ	n	w	θ	n	
VS375	0.034	0.95 cm	1.84 cm	45°	6	0.95 cm	45°	5				20.3 cm
VS500	0.025	1.15 cm	1.84 cm	45°	6	1.15 cm	45°	5				20.3 cm
VH500	0.030	1.15 cm	1.84 cm	45°	6	1.15 cm	45°	5				20.3 cm
HVD-500	0.032	1.15 cm	2.33 cm	45°	6	1.15 cm	45°	5				20.3 cm
4 Pass	0.043	2.54 cm	6.5 cm	30°	1	2.54 cm	60°	3	3.96 cm	30°	3	25.4 cm

In order to find the overall efficiency of a vane the equation below is repeated for as many different vane baffle geometries (e.g. A,B, and C) as are present.

$$\eta_{Vane}(d_d) = \sum_{i=1}^{n} \eta_{VaneBaffle\ i}(d_d) + [100 - \eta_{VaneBaffle\ i}(d_d)] \times [\eta_{VaneBaffle\ i+1}(d_d) / 100]$$

The geometries of SEPCO PROCESS, INC.'S two articu-lated vane styles with no pockets that may be used in either vertical or horizontal flow, are shown in Table 5 with depictions adjacent to Figures 5 and 6. At a given droplet diameter, d_d, overall percent efficiencies for mesh-vane combinations (or by analogy for multiple layers of mesh as well) are found by the formula below:

$$\eta_{Overall}(d_d) = \eta_{Mesh}(d_d) + [100 - \eta_{Mesh}(d_d)] \times [\eta_{Vane}(d_d) / 100]$$

COMPARING MIST ELIMINATOR PERFORMANCE

A challenging mist elimination application, such as the selection of the best mist eliminator for a propane compressor suction scrub-ber in an LNG plant, illustrates the use of these formulas. Physical parameters are an operating pressure of 90 PSIG (6.2 barg), an operating temperature of 150° F (65.5° C), vapor density of 1 lb/ft^3 (16 kg/m^3), vapor viscosity of 0.008 cP, a liquid density of 31.1 lb/ft^3 (498 kg/m^3), and a liquid viscosity of 0.08 cP. The figures below compare the performance at these conditions of SEPCO PROCESS, INC. 6 inch (15.2 cm) thick mesh pads, vanes, their com-binations, and a typical 4 pass competitor vane as shown adjacent to Figure 8 with details in Table 5. In Figure 5 pressure drops are plotted upto the allowable K-Factor for various mist eliminators, while their efficiencies at 6, 8, and 10 microns are plotted upto their allowable K-Factors in Figures 6, 7, and 8; respectively. The designa-

VS-375

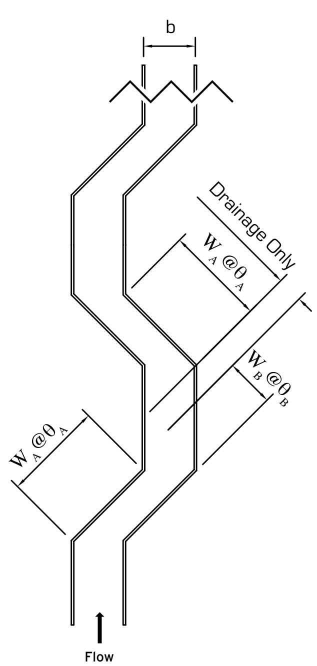
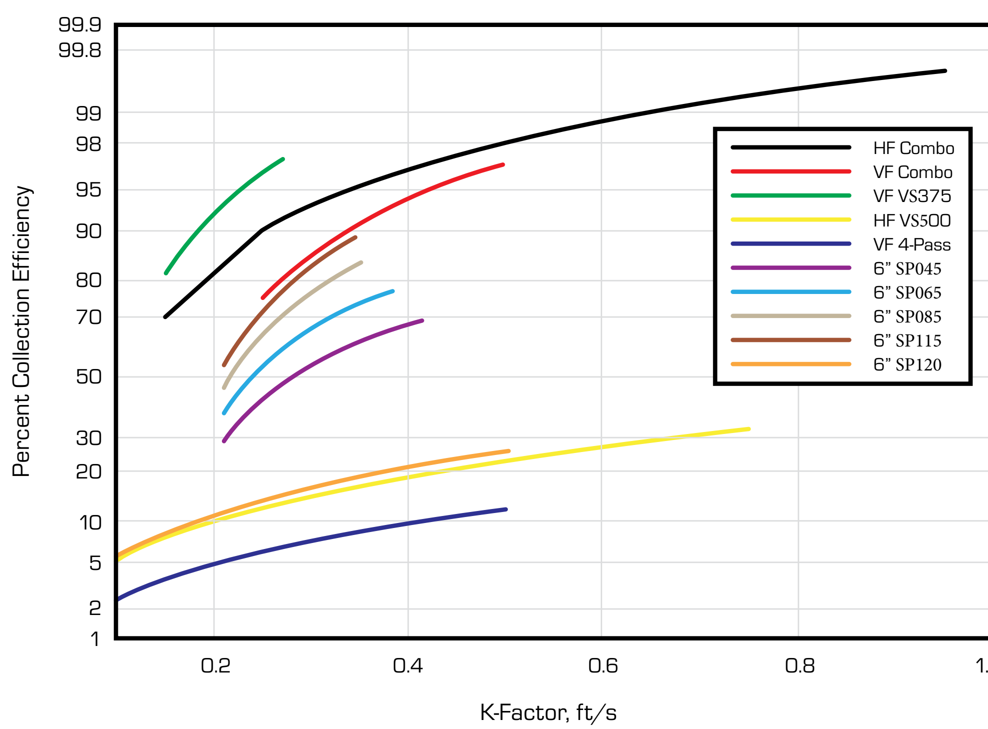


FIGURE 6 COLLECTION EFFICIENCIES FOR SIX MICRON DROPLETS



tion "HF Combo" indicates 4 inch (10.2 cm) thick SP120 in front of an VH500 vane in horizontal flow, while the designation "VF Combo" indicates 6 inch (15.2 cm) thick SP115 below a VS500 vane in vertical flow.

Vessel Flange-to-Flange Pressure Drops

Selection of the proper mist eliminator for a given application is often dependent upon the available pressure drop. The pressure drops across the mesh pad and vane mist eliminator internals can be obtained with the formulas above. When **English units** are used, the following F_{DP} formulas allow the derivation of the pressure drop in inches of water column across the entire vessel, flange-to-flange.

ΔP_{Inlet}	=	$0.003\ \rho_{mix}\ v_{mix}^2$	Inlet nozzle
ΔP_{Outlet}	=	$0.0015\ \rho_g\ v_g^2$	Outlet nozzle
$\Delta P_{Flow\ Distributor}$ (Perforated Plate)	=	$0.008\ \rho_g\ (v_g / OA)^2$ where OA = fractional open area of the perforations	Flow Distributor
$\Delta P_{Flg\text{-}Flg}$	=	$\Delta P_{Inlet} + \Delta P_{Mist\ Eliminator\ Element(s)} + \Delta P_{Flow\ Distributor} + \Delta P_{Outlet}$	

Upon expansion into a vessel back-mix eddies are formed which doubles the pressure drop over that in the outlet nozzle. As was mentioned above, the Sepco Process, Inc.

In order to distribute the process flow evenly the sum of the mist eliminator and flow distributor needs to be in the 3 to 6 inch (7.5 to 15 cm) WC range. This means that the fraction open area of the perforations, OA, needs to be in the range of 0.05 to 0.20. Also, in order to assure even flow through the entire depth of the mist eliminator element the flow distributor must be installed on top of a full 1 inch (2.5 cm) height mesh pad grid or on top of a straight vertical baffle, minimum 0.5 inch (1.3 cm) long, parallel to the flow path.

MIST ELIMINATION ADVICE BY INDUSTRY

Refineries

Wire mesh pads were first installed in refineries in 1947 by Otto York. The construction he started with had 12 lb/ft³ (192 kg/m³) of 0.011 inch (279 micron) stainless steel wire, now SEPCO PROCESS, INC. Style SP115. This has been an industry standard ever since for fractionation towers and compressor suction drums. In vacuum towers that have heavier and more asphaltic mists, as well as coke particles, this design was found to have too much potential. A 5 lb/ft³ (80 kg/m³) version with a "herringbone" crimp in the mesh laminations imparted to the mesh was also developed. (Typically the corrugations are on a straight 45° angle to the mesh

VK500

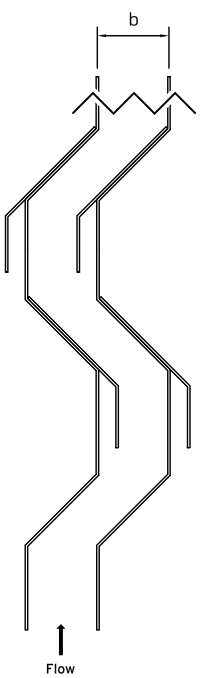
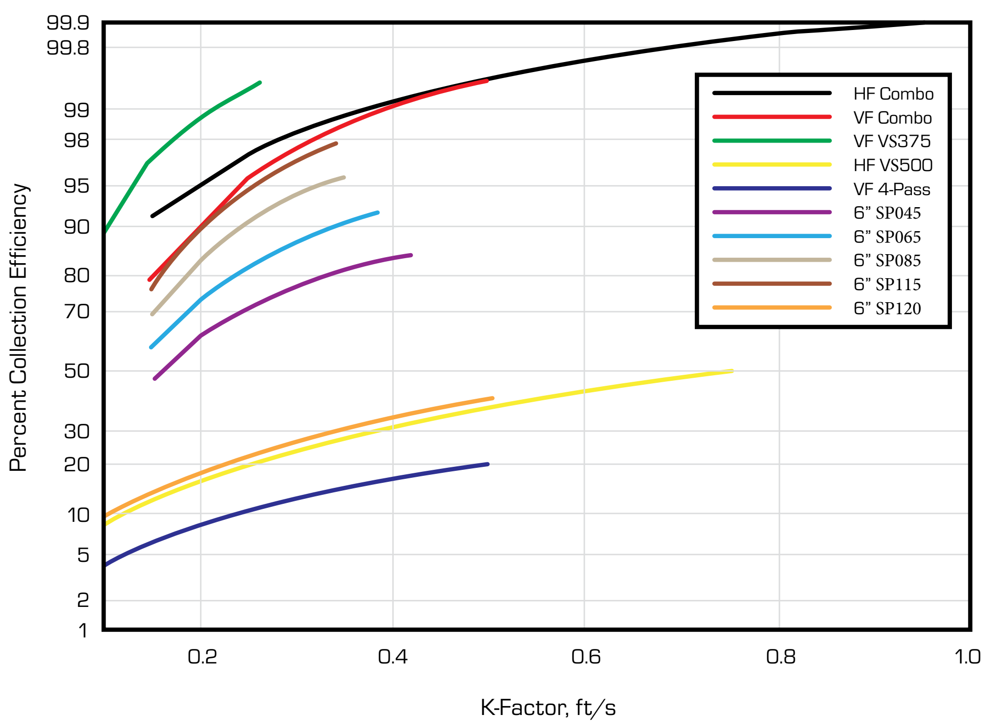


FIGURE 7 COLLECTION EFFICIENCIES FOR EIGHT MICRON DROPLETS



ribbon and the pad's high void fraction is developed by crossing the crimps of alternating layers). This is now SEPCO PRO. Style SP045. This light construction also yields a high capacity and a low pressure drop as seen in Tables 2 and 4. It is likely that the majority of mesh pads installed in both the HPI and CPI around the world are manufactured as the general-purpose compromise between these two, at 9 lb/ft^3 (144 kg/m^3) with 0.011 inch (279 micron) wire, SEPCO PROCESS STYLE SP085. The formulas above allow an accurate determination of which style is best for a given application.

Over the years various techniques have been promoted as improvements in gas handling capacity based on improved liquid drainage, such as layering of several progressively heavier mesh styles and rolls of mesh attached to the bottom grids. However, as they do little to prevent re-entrainment at high K-factors, their benefits over the classics are marginal at best. Indeed, greater cognizance of the importance of vapor distribution and inlet devices, such as shown in Figure 2, came about at the same time and in effect gave the traditional constructions a hidden boost in their capacity.

As shown in Table 1, vane baffle mist eliminators, such as SEPCO PROCESS INC. VS500, do have very significant benefits in capacity and pressure drop. Their losses in capture efficiency, meanwhile, are only on the very finest and, therefore, lightest droplets (less than ~15 microns). Even this disadvantage disappears as a mesh pad becomes fouled over the months and years in the notoriously dirty refinery applications. On a square foot basis in stainless steel, VS500 is about two and a half times as expensive as 6 inch (152 mm) of SP085 with top and bottom grids. Therefore a $5K mesh pad costs about $12.5K as a vane. However, as is very typical, that savings be-comes meaningless when it is discovered during a 3 to 5 year turn-around that the mesh pad has to be replaced on as an emergency basis and premiums for 'hot-shot' delivery and overtime pay for the maintenance staff performing the installation have to be paid.

Gas Plants

Gas plants have always used high-priced solvents, such as glycols and amines, for the removal of water vapor, sulfur compounds, and carbon dioxide, the loss of which from tray and packed columns has a dramatic effect on a facility's OPEX factors. Also, it is very important to protect compressors with high efficiency internals in their suction drums downstream of inter-stage coolers. Here again the classics are tried-and-true. In the 1950's the mesh styles with 0.006 inch (152 micron) wire, such as SEPCO PROCESS INC.Style SP120, became very popular for these services.

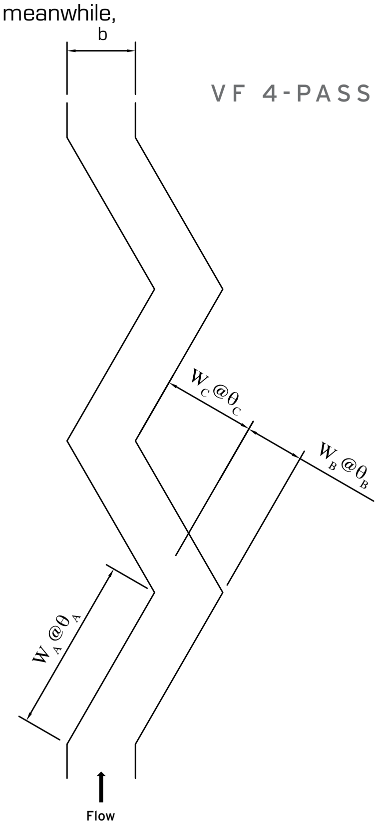
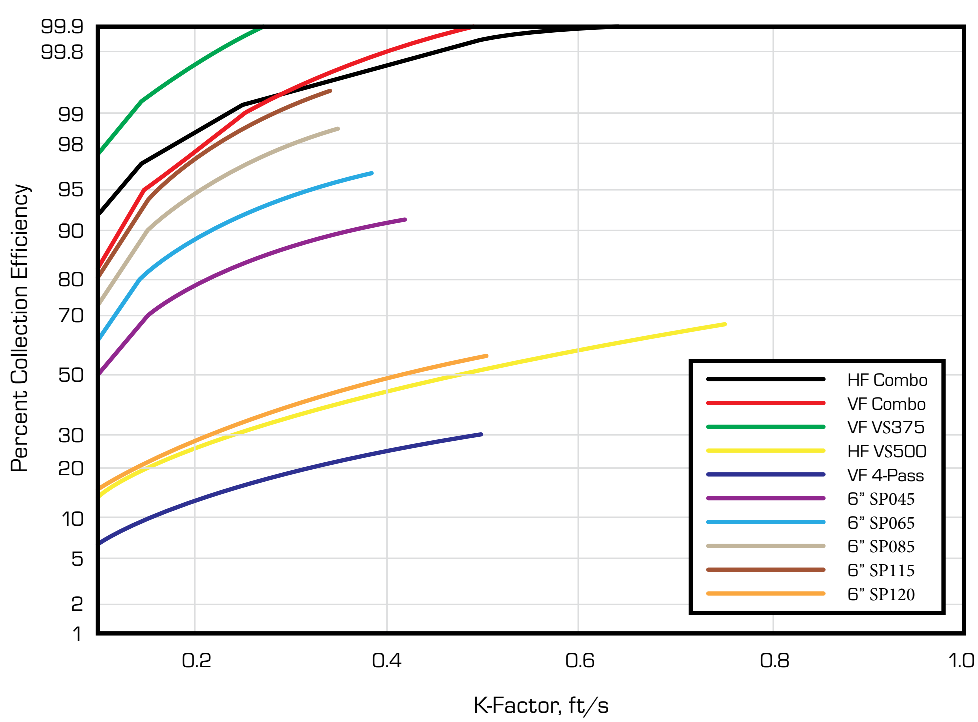


FIGURE 8 **COLLECTION EFFICIENCIES FOR TEN MICRON DROPLETS**



As the prices for solvents continued to increase, so did the demand for improved mist eliminators, with a tight spec of only 0.1 gallons allowed to be lost per million standard cubic feet of gas processed (0.013 ml/Nm^3). The solutions that came to the market were the co-knits of wire with fiberglass, fluorocarbon, and polyester yarns (Styles SP242, SP388, and SP670, respectively) that have target filaments between 9 and 30 microns in size. However, as in shown in Tables 1 and 3, they do have lower capacities for the flow of both gas and liquid. The benefits of adding a lower layer of all-metal mesh were soon recognized. SEPCO PROCESS, INC. Styles SP41340, SP4485, and SP-4775 employ this technique. Indeed when the upper layer of co-knit is increased to 6 inch (152 mm) to 12 inch (304 mm) losses of well under 0.05 gallon/MMSCF (0.007 ml/Nm^3) have been reported. Consult Tech Support at SEPCO PROCESS, INC. for additional details. Especially since the development of high-capacity double-pocket vanes in the 1980's, such as SEPCO PROCESS, INC. HVD-500, high-performance mesh and vane combinations have become very popular for the mist elimination internals in gas plant KO Drums and Absorption Towers. The effect of increased droplet collection by inertial impaction on fine wires is synergized with the higher allowable vapor velocity resulting from the shielding of the liquid phase by a pocketed vane mist collector. Typically 4 inch (102 mm) to 6 inch (152 mm) of SP120 or SP115 are used upstream of one of the pocketed vanes in horizontal flow situations. The same pre-conditioning mesh elements are used in vertical flow with vanes without pockets (VS375 or VS500) used when the K-factor is less than or equal to 0.5 ft/s (0.15 m/s) SEPCO PROCESS, INC. VD-500 with suitable liquid collection sumps and downcomer piping may be used when the K < 0.95 ft/s (0.29 m/s) (the effect mentioned on page 4 must be kept in mind). Additional collection of ultra-fine droplets is possible with co-knit mesh in combination with vanes. However, their high surface areas are also excellent collection points for tramp solid particles, so they should not be used unless the gas stream is known to be very clean. Consult Tech Support at SEPCO PROCESS, INC. on all these issues.

Upstream

With oil and gas exploration becoming common at 10,000 feet (3,048 m) below sea level, mist eliminators are being required to operate at higher temperatures and pressures. Even at the high K-factors allowed by double-pocket vane, superficial velocities are too slow for inertial impaction when they act alone, so a conditioning mesh pad becomes an imperative. Indeed, above 1450 PSIG (100 barg) axi-flow demisting cyclones become much more common, although still with a mesh pad pre-conditioner. Their high pressure drop requirements and high cost are justified by their high capacity keeping vessel diameters, and hence wall thicknesses, at a minimum.

Upstream applications by definition have the most fouling potential, so vane mist eliminators have replaced many mesh pads here. See also the section above on Gas Plants for the proper design of mesh/vane combinations in upstream applications.

Air Pollution Control Scrubbers

Air Pollution Control Scrubbers often are used in highly corrosive, but near-ambient temperature and pressure conditions. Here plastic constructions become advantageous from the aspects of both cost and useful life. Plastic knitted mesh is rarely given a crimp, so its void fraction falls well below that of metal (see Table 2).

A thickness of only 4" (102 mm) of mesh is typically used in these towers for a nominal 99% removal of droplets >10 microns in order to minimize pressure drop. SEPCO PROCESS, INC Styles SP1421 and SP14213 are all-polypropylene co-knits of mono and multi-filament yarn that can efficiently remove highly acidic and/order corrosive droplets as small as 2 microns, thereby protecting the environment and local personnel.

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NOMENCLATURE

	Quantity	Engineering	
		English	Metric
a	Area	ft^2	m^2
a_c	Acceleration due to centrifugal force	ft/s^2	cm/s^2
b	Distance between vane blades	ft	cm
C_D	Drag coefficient		
d_d	Droplet diameter	inch	cm
D_{98}	Droplet diameter which is collected with 98% efficiency	inch	cm
D_d	Droplet diameter	ft	m
d_e	Equivalent diameter of mesh loop	inch	cm
d_w	Diameter of wire or monofilament	inch	cm
D_w	Diameter of wire or monofilament	ft	m
F_{DP}	Pressure drop coefficient		
F_{LL}	Discount factor for liquid loading		
F_μ	Discount factor for liquid viscosity		
h	Thickness of a mesh pad or layer	inch	cm
H	Thickness of a mesh pad or layer	ft	m
K	Capacity coefficient	ft/s	m/s
L	Volumetric flow rate of liquid/area	$ft^3/hr\text{-}ft^2$	$m^3/hr\text{-}m^2$
N_S	Separation number		
OA	Fractional open area for perforations		
Qg	Volumetric flow rate of the gas	ft^3/hr	m^3/hr
Q_l	Volumetric flow rate of the liquid	ft^3/hr	m^3/hr
r_d	Droplet radius	inch	cm
Re	Reynolds number		
SG	Specific gravity of the liquid		
V_d	Droplet volume	$inch^3$	cm^3
v_g	Velocity of gas	ft/s	m/s
v_l	Velocity of liquid	ft/s	m/s
v_t	Terminal settling velocity	ft/s	m/s
w	Length of vane baffle	inch	cm
W_l	Mass flow of liquid phase	lb/hr	kg/hr
W_g	Mass flow of gas phase	lb/hr	kg/hr

GREEK SYMBOLS

	Quantity	Engineering	
		English	Metric
ΔP	Pressure drop	inch of liquid	mm of liquid
η_{Mesh}	Collection efficiency	percent	percent
η_{vane}	Collection efficiency	percent	percent
η_w	Collection efficiency	fraction	fraction
θ	Baffle's angle of inclination to flow	degrees	degrees
$\theta_{L\text{-}S}$	Contact angle droplet/wire	degrees	degrees
μ_g	Viscosity	poise	poise
μ_l	Viscosity	poise	poise
ρ_g	Density	lb/ft^3	gm/cm^3
ρ_l	Density	lb/ft^3	gm/cm^3
$\sigma_{L\text{-}G}$	Liquid/gas surface tension	dyne/cm	dyne/cm
$\sigma_{L\text{-}S}$	Liquid/gas surface tension	dyne/cm	dyne/cm

CONVERSION FACTORS

Gas Processing Data	
English	Metric
24.41 Nm^3	1 kmol
Normal conditions at 101.325 kPa and 0°C	
379.3 SCF	1 lb-mol
Standard conditions at 14.696 psia and 60°F	
37.3 SCF	1 Nm^3
(MW × bara) / (0.0831 × °K × z)	ρ_g, kg/m^3
Power 3412 Btu/hr	1 kW
Flowrate 1 m^3/hr	4.40 US gpm
4.4 gpm	1 m^3/hr
Temperature 5/9 (°F - 32)	°C

Oil Processing Data	
Crude Oil SG	141.5 / (131.5 + °API)
1 API barrel (bbl)	159 Litres 42 US gal 35 imp gal 5.61 ft^3
Viscosity cP	cSt × SG

General Conversions	
English	Metric
Length 3.281 ft	1 m
Area 10.76 ft^2	1 m^2
Volume 35.31 ft^3	1 m^3
Mass 2.205 lb	1 kg
Density 0.0624 lb/ft^3	1 kg/m^3
Pressure 14.5psi	1 bar
Power 3412 Btu/hr	1 kW
Flowrate 4.40 US gpm	1m^3/hr
Temperature 5/9 (°F - 32)	°C

Mechanical Data	
Pressure vessel thickness:	ASME 8 Div.1 $t = [(P \times D_i) / 2(SE - 0.6P)] + c$
Vessel volume with 2:1 elliptical heads:	$V = (\pi \times \{D_i^2 / 4\} \times L + 2(\pi \times D_i^3 / 24)$
ANSI Flange Rating	Max. Pressure at 100°C
150#	17.7 barg
300#	46.4 barg
600#	92.8 barg
900#	139.2 barg
1500#	231.9 barg

Rules of Thumb	
Pump Power:	$kW = (0.0278 \times \Delta bar \times m^3/hr) / \eta$
Liquid Pipe Size:	$d\,(in) = [(kg/h)^{0.45} / 3 \times (\rho_l)^{0.31}]$
Gas Pipe Velocity (maximum):	$v\,(m/s) = 123 / \rho_g^{0.5}$
Vessel Weight (Cylinder):	W(kg) = 35 × D(m) × t(mm) × L(m)

Heat Transfer Data	
Enthalpy 0.4299 Btu/lb	1 kJ/kg
Specific heat 0.2389 Btu/lb°F	1 kJ/kg °C
Thermal conductivity 0.5778 Btu/h ft°F	1 W/m °C
Heat Ttansfer co-efficient 0.1761 Btu/h ft^2 °F	1 W/m^2 °C

SEPCO PROCESS, INC.

Mist Eliminator Design Manual

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