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Wire mesh mist eliminators

The development of composite meshes has increased the separation efficiency for removal of fine particle size mists.

THE KNITTED WIRE MESH mist eliminator, commonly specified as the Demister, has gained extensive industrial recognition as a low cost and efficient means for removal of entrained liquid droplets from vapor and gas streams. The wire mesh entrainment separator is installed without difficulty in process equipment, such as evaporators, scrubbers, and distillation columns. The only required addition to equipment up to 6-ft. diameter is a support ring fixed to the inside of the vessel to hold the mist eliminator assembly which consists of the wire mesh sandwiched between a bottom support and top hold-down grid. In larger vessels intermediate supports are required in addition to the annular ring. Figure 1 shows a one-piece mist eliminator where this type can be inserted into the vessel through the open end of the equipment. The sectional type construction is shown in Figure 2 for larger vessels where installation is to be made through a manhole. The photograph also shows the annular rings and internal supports usually furnished by the vessel fabricator.

Although knitted wire mesh has been used by industry for a broad range of entrainment elimination uses, the volume of fundamental work published regarding their performance characteristics is small. The work of Satsangee (*1*), Stein (*2*) and Schurig (*3*) was concerned primarily with wire mesh as column packing and contacting media and not specifically for entrainment elimination. The detailed investigation of Carpenter (*4*) studied wire mesh as an entrainment separator in an evaporator handling salt solution and defined the efficiency, pressure drop, and capacity of the knitted wire structure.

As generally used, the knitted wire mesh mist eliminator consists of a bed, usually 4 to 6-in. deep, of fine diameter wires interlocked by a knitting operation to form a wire mesh pad with a high free volume, usually between 97 and 99%. The wide range of wire diameter and mesh construction have been presented by York (*5*). Characteristics of two typical mesh styles widely used are:

York style No.	Void fraction	Specific surface area, sq.ft./cu.ft.
421	0.977	110
931	0.99	46

The style 421, having a greater surface area, will effect a higher degree of separation. The style 931 is designed for operation where the entrainment is particularly dirty or viscous, or where liquid entrainment load is high. Both styles are fabricated using an 0.011-in. diameter wire. Wire mesh styles of other wire sizes and characteristics are manufactured to

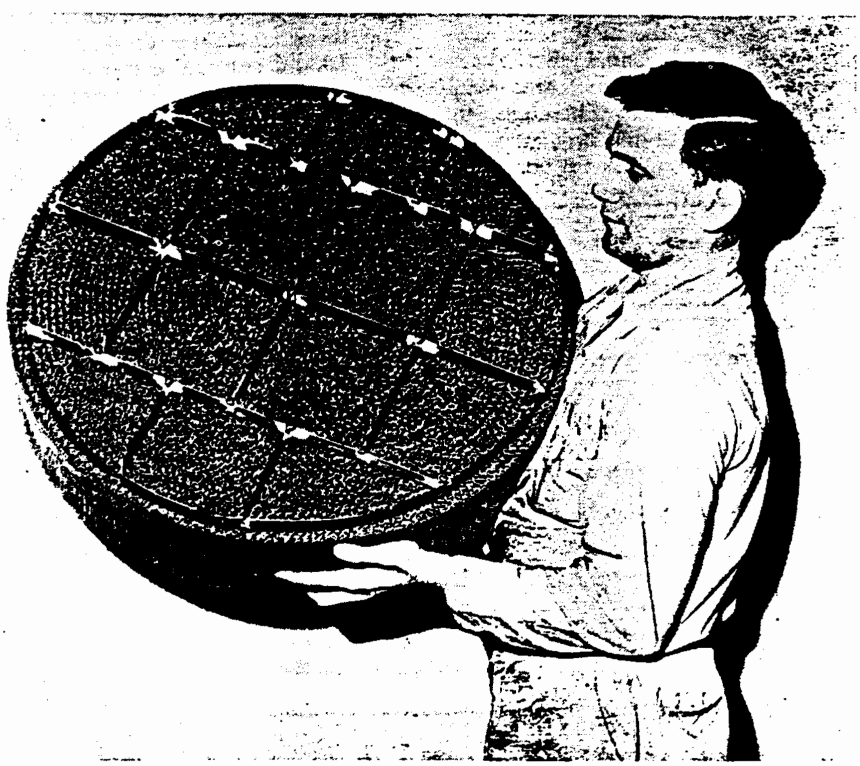

Figure 1. A one-piece nickel wire mesh eliminator for insertion into vessel through open end of equipment.

meet the requirements of unusual operating conditions. The wire mesh construction is altered to change performance characteristics such as entrainment removal efficiency, liquid drainage rate, gas handling capacity, and pressure drop. Separation efficiencies greater than 99.9% are obtained over a wide velocity range.

Pressure drop

The pressure drop across the wire mesh is sufficiently low, usually less than an inch of water, to be considered negligible for most applications. The effect of the low pressure drop becomes more significant in mesh design for vacuum distillation and for equipment where the prime mover is a blower or fan. Pressure drop assumes importance in an existing blower driven system since an increase in back pressure is accompanied by a reduction in delivered gas volume. In terms of power consumption, each inch of water pressure drop requires 0.158 theoretical hp/1,000 cu. ft./min. Therefore, a correlation to predict pressure drop may be important.

The pressure drop through wire mesh is influenced by gas and liquid rates as shown in Figure 3 and 4. Flow of gas through the mesh is predominantly turbulent with the slope of the dry curve about 1.8. As is the case with packed towers, the pressure drop rises with increased liquid load since at higher entrainment rates, the lower surface of the mesh more completely fills with liquid thereby reducing the cross-sectional area available for vapor flow. Therefore, the points of incipient flooding at A and final reentrainment at B occur at lower velocities as entrainment loads become heavier.

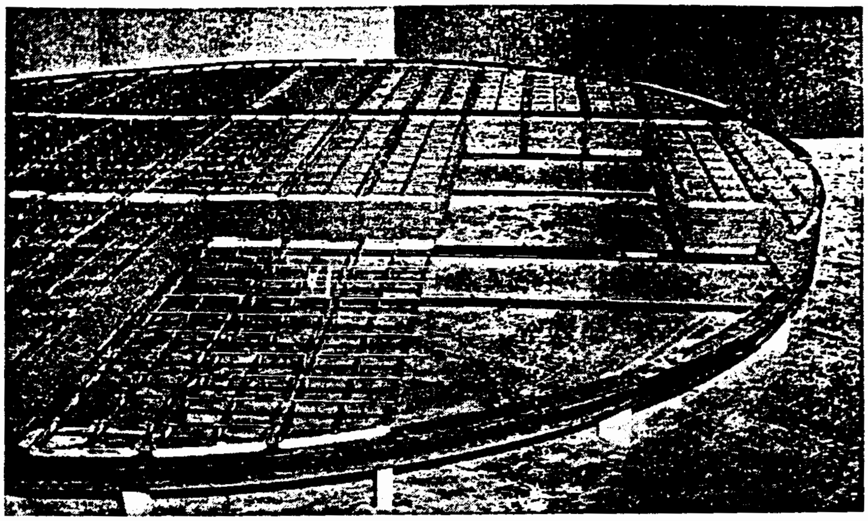

Figure 2. Partial asssembly of sectional wire mesh eliminator of stainless steel with bottom and top grids for a 17½-ft. diameter refinery vacuum tower.

Liquid collection

At entrainment loads less than 10 lb./hr.-sq.ft. collected liquid in the mesh forms as discrete droplets on the wires. These fall off as the force of gravity on the droplet overcomes the combined forces of the rising gas and surface tension which tend to hold the drop on the wire. At higher liquid loads, a clearly defined reservoir of liquid is visible in the mesh. As gas velocity is increased at a high entrainment load, three distinct conditions of liquid activity take place. The three conditions that occur are:

1. Liquid enters the mesh and collects in an active reservoir comprising a depth of only 1 to 2 in. at the bottom of the wire mesh. This liquid reservoir is about the same from low gas flow up to point A on Figure 3 and 4.

2. Beyond Point A, the bubbling liquid reservoir rises higher into the mist eliminator with each additional increase in gas rate. Liquid now occupies a significant part of the void space and the mesh becomes internally flooded. Pressure drop rises more sharply and cycles somewhat.

3. As the gas rate is further increased, pressure drop cycles greatly as the liquid reservoir is lifted to the top surface of the mesh at Point B. The liquid no longer freely drains from the bottom surface and reentrainment occurs from the top of the wire mesh.

Carman (6) developed a correlation for solid granular materials. A similiar correlation for wire mesh is presented in Figure 5 where pressure drop is calculated with the expression:

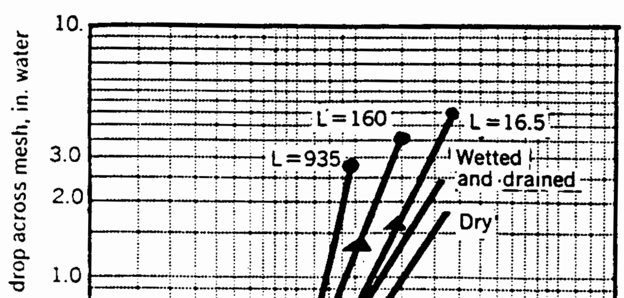

Figure 3. Pressure drop for 6-in. wire mesh mist eliminator, mesn style 421, at various conditions of liquid loading.

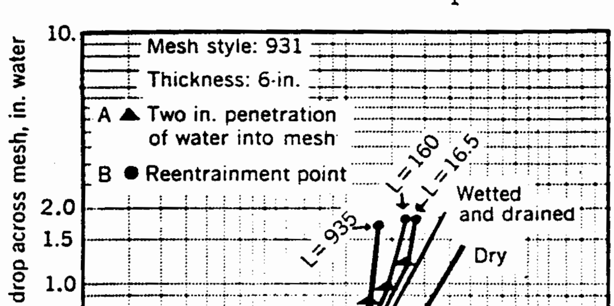

Figure 4. Pressure drop for 6-in. wire mesh mist eliminator, mesh style 931, at various conditions of liquid loading.

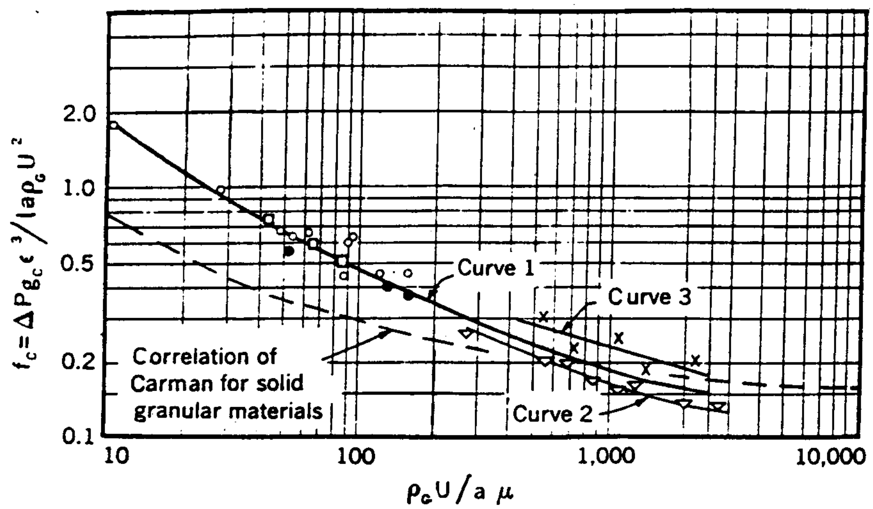

Figure 5. Friction factor, f_c, versus Reynolds number, Rc, for wire mesh entrainment separator without entrainment load.

$$\Delta P = f_c la \rho_G U^2 / g_c \epsilon^3 \quad (1)$$

where f_c is a function of Reynolds number:

$$Re = \rho_G U / a\,\mu \quad (2)$$

Friction factor, f_c is plotted against Reynolds number. Since pressure drop across wire mesh is commonly expressed in inches of water, conversion from the units of lb./sq. ft. for ΔP from Equation 1 is:

$$\Delta p = 0.193\,\Delta P \quad (3)$$

Experimental data

Experimental data, based on air passed through 6-in. thick dry wire mesh are shown in the region of Reynolds numbers greater than 200. At values less than this, air velocity and the small pressure drop readings across 6-in. thick wire mesh become difficult to measure precisely. Therefore, to explore the region of lower Reynolds numbers, the pressure drop of water passed through wire mesh was studied. These data are shown in the left-hand portion of Figure 5. Also shown are the data of Satsangee (*1*) and Schurig (*3*) for beds of dry packing. These show good agreement with the drawn curve.

Most of the observed data points fall on or close to Curve I, and for the purpose of clarity are not shown. For the specific data points shown which do not fall on the curve the maximum deviation is about 25%. Curves 2 and 3 of Figure 5 represent consecutive runs using the same equipment. These curves are based on the investigation by Poppele (*7*) of the style 931 and 421 mist eliminators and reveal an important difference between two basic wire mesh constructions. In the one case the wire mesh consists of individual crimped layers, each one of which is actually a nested double layer. The style 421 is typical of this construction and is represented by Curve 2.

In the other case, represented by Curve 3, the nested double layers are separated into single mesh layers and the crimp directions alternated (*13*). This not only increases the percentage voids for the same wire surface, but improves homogeniety of wire distribution and minimizes the sheltering of one wire behind another, as is the case with the nested double layer construction. Hence, the pressure drop is slightly higher than would otherwise be predicted by the correlation. This indicates more effective wire surface area exposed to the gas stream. More important from the mist elimination standpoint is the fact that the greater effective surface area results in improved wire mesh efficiency for a given number of wire targets. The style 931 is this specially oriented mesh construction. Several other mesh styles of greater efficiency are now available in this special design.

Liquid load pressure loss

The total pressure drop across wire mesh is the sum of the pressure drop across the dry mesh, as calculated using Figure 5, plus the additional pressure loss contributed by the liquid load within the mesh. This may be expressed as:

$$\Delta p_T = \Delta p_D + \Delta p_L \quad (4)$$

The effect of entrainment loading on pressure drop is calculated using Figure 6 and 7. Although the curves are for water, more viscous liquids would, at the same air rate, cause greater pressure drop. The curves show on the ordinate the added pres-

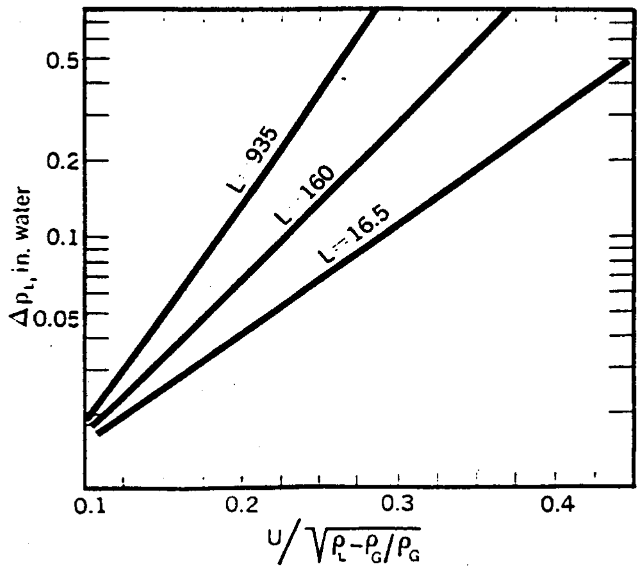

Figure 6. Pressure drop correction for entrainment load for style 421 wire mesh.

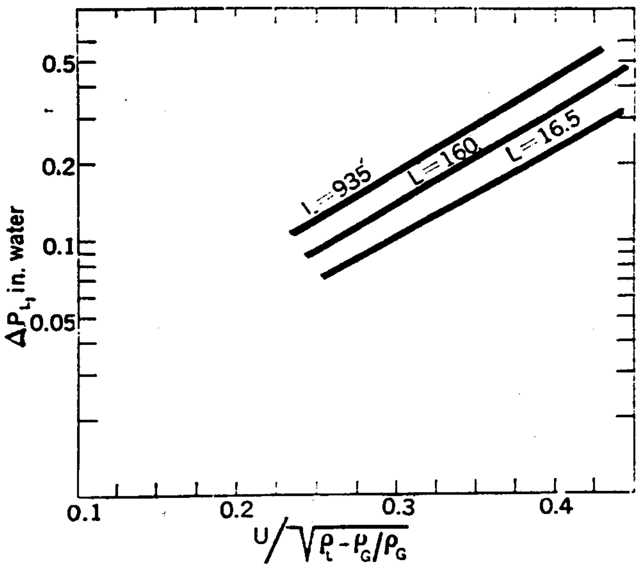

Figure 7. Pressure drop correction for entrainment load for style 931 wire mesh.

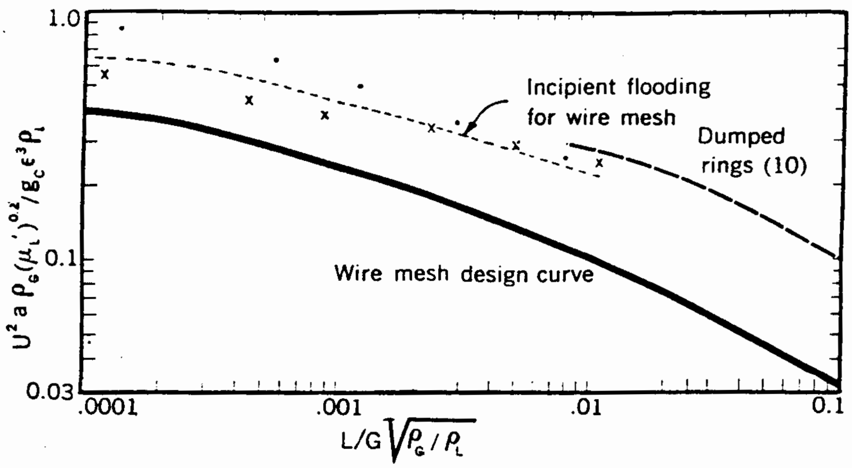

Figure 8. Effect of liquid entrainment load on allowable gas velocity.

sure drop quantity, Δp_L, from Equation 4, which must be added to the calculated dry pressure drop from Figure 5. The ordinate is independent of packing height since at a given gas and liquid load the entrainment will penetrate a finite distance into the wire mesh regardless of the ultimate thickness. This is a situation which departs from the usual means for reporting pressure drop in the literature for wetted column packing where the liquid flows down the entire depth of packing counter-current to the rising gas. In this latter case the effect of the liquid flow is applied as a correction factor by which the calculated total dry pressure drop is multiplied.

Allowable velocity

Several factors govern the allowable gas velocity through wire mesh for a given set of conditions; they are:

1. Gas and liquid density
2. Surface tension of liquid
3. Viscosity of liquid
4. Wire mesh specific wire-surface area
5. Liquid entrainment loading
6. Suspended solids content

Of these, the liquid and gas density have the most pronounced influence on design velocity. Application of the Souders-Brown expression (*8*) as a convenient means for calculation of allowable vapor velocity for wire mesh mist eliminators based on gas and liquid densities has been proposed by York (*5*), using the equation:

$$U = K[(\rho_L - \rho_G)/\rho_G]^{0.5} \qquad (5)$$

The value of K that is commonly used is 0.35 and is acceptable for most entrainment separation purposes; however, when liquid viscosity, and entrainment loading are high, or the liquid very dirty, a reduced value for K must be used. Lower K values were also found necessary as reported by Schroeder (*9*) when surface tension is reduced in a water system with the use of wetting agents.

The influence of liquid entrainment loading upon K value has been investigated by Poppele for an air-water system (*7*). The data for the point of incipient flooding for the two wire mesh mist eliminators investigated are shown in Figure 8 together with the flooding velocity correlation of Sherwood, Shipley and Holloway for dumped rings (*10*). Also shown is a recommended design curve inasmuch as cleanliness of liquid and surface tension are variables not always precisely known nor easily controlled. While the load upon wire mesh is commonly referred to in terms of vapor load alone, this correlation shows that both vapor and liquid comprise the total load for the mist eliminator and that a reduced rate of one will allow an increase in the rate of the other.

Non-metallic mesh

The austenitic stainless steels are the most commonly used materials of construction; they possess good mechanical strength and resist satisfactorily a wide variety of corrosive process fluids. Mesh consisting of knitted non-metallic monofilaments has been developed for applications where they offer an advantage over metallic constructions. Included in such applications are operations involving sulfuric acid, hydrochloric acid, hydrofluoric acid, chlorosulfonic acid, wet chlorine gas, formic acid, fatty acids, pickling bath fumes, and spin bath liquor. Polyethylene and polypropylene mesh mist eliminators are highly resistant to chemical attack but generally are limited in use to temperatures below 150° to 170°F. Teflon mesh (*11*) has exceptional resistance to acids, alkalis, and organic solvents, and may be used at temperatures as high as 300°F.

Allowable flow rates are about the same as for the metallic mist eliminators; pressure drop is less than 1 in. water within the allowable velocity range. As would be expected, the mechanical strength of the plastic mist eliminators is not equal to that for the wire mesh type. However, the plastic filament is entirely adequate for mist elimination purposes since the structure is subject to negligible stress during operation.

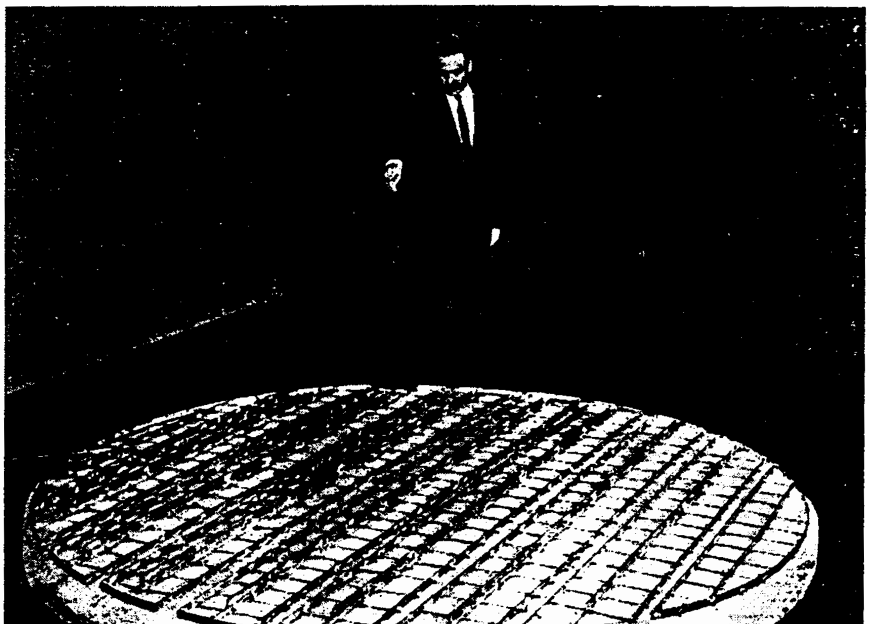

Figure 9. Teflon mist eliminator, 9½-ft. diam., with Hastelloy C grids.

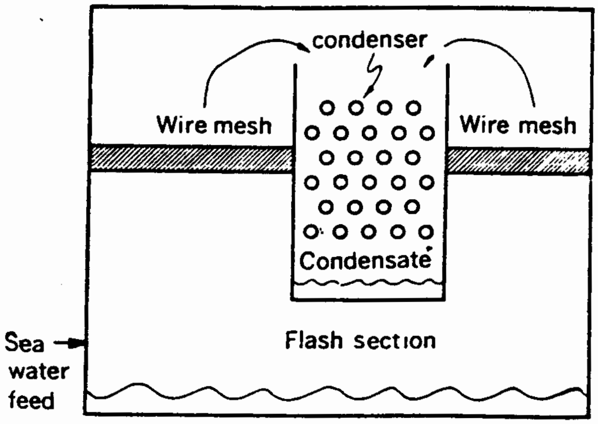

Figure 10. Wire mesh mist eliminator location in a one-million gal./day sea water evaporator.

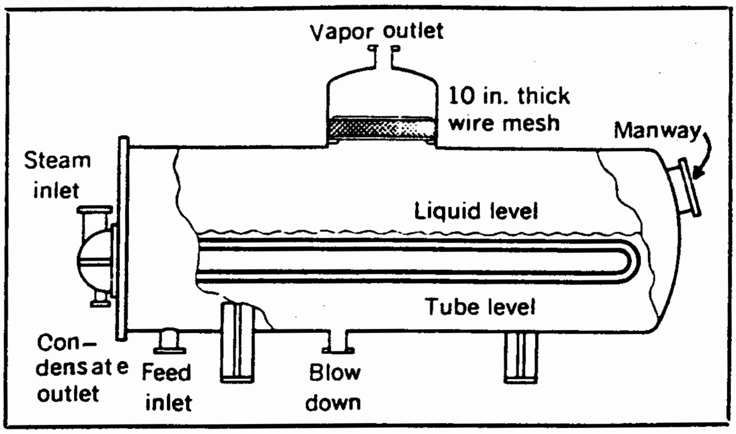

Figure 11. Wire mesh mist eliminator location in horizontal boiler feed water evaporator.

Stainless steel, Monel, Carpenter 20, Hastellov, or Titanium are frequently used as support grid materials for the plastic mesh. A Teflon mist eliminator, 9½-ft. diameter, with Hastelloy C sandwich grids is shown in Figure 9. Support grids of metal with all surfaces coated with polyvinyl chloride, phenolic resin, or rubber are available. If metals are to be avoided entirely, polypropylene or Teflon support grids are used; these are not as rigid as metal grids.

Composite mesh constructions

An important and useful development in knitted mesh eliminators is the incorporation of a multifilament yarn into the basic wire mesh structure. In addition to glass fiber yarn, synthetic and natural fibers can be used such as Dacron, Orlon or cotton, depending upon the requirements imposed by the process conditions. Without the carefully designed wire mesh reinforcement the multifilament would be subject to the usual affliction common to beds of loosely packed glass and synthetic fibers whereby settling results in excessive pressure drop and disintegration. The potential advantage of the extensive surface of the fine filament is thereby defeated. The composite wire and multifilament construction, however, maintains excellent spatial distribution of the multifilament and eliminates settling by virtue of the support contributed by the interlocking wire mesh framework. The uniform, rigidly held, spacing of the fine filaments insures maximum exposure of the fine multifilament component to the mist-laden fluids flowing through the structure.

The composite meshes have demonstrated excellent separation efficiency for removal of droplets falling below the particle size range capabilities of the conventional wire meshes. Typical applications where the advantages of the composite styles are best realized are acid mist elimination from stacks, oil mist removal from compressed gases, and elimination of fine fog resulting from condensation of a liquid from a saturated gas. The particle size of mist so generated is well below that for entrainment found in distillation columns, absorbors, and evaporators where wire mesh eliminators are capable of a satisfactory high degree of separation.

Extending performance

The allowable velocity of the composite mesh mist eliminators is approximately one-half of that for the wire mesh styles. Pressure drop will range between 3 to 10 in. of water for most applications and higher in special instances where the separation of mist from gas is known to be extremely difficult. Therefore, the composite styles are not intended to replace the wire mesh in locations where excellent performance is already being obtained, but to further extend the range of performance of knitted mesh into new areas of more difficult mist removal.

As an example, removal of acid mist from effluent gas from sulfuric acid absorbors presents varying degrees of difficulty. The final acid

Table 1. Efficiency of sulfuric acid removal from absorber stack gas.

Wire mesh filter, 2-stage, velocity 12 to 15 ft./sec.

Pressure drop, in. water	Concentration Mg. H_2SO_4/ cu. ft. Inlet	Outlet	Eff., %
1	8.8	0.70	92.5
¾	4.1	0.74	82.0
1¼	13.8	0.92	93.4
1¼	66.9	0.77	98.9
1½	32.5	0.98	97.0
1½	13.0	0.76	94.1

Table 2. Comparison of conventional and composite mist eliminator in sulfuric acid mist removal.

Mesh type two-stage	Gas velocity ft./sec.	Concentration mg. H_2SO_4/cu. ft. inlet	outlet	Pressure drop, in. water
Wire mesh	15-18	38-150	2.1-2.3	1.5-2.0
Composite	9-18	25-200	0.7-1.7	2.5-9.0

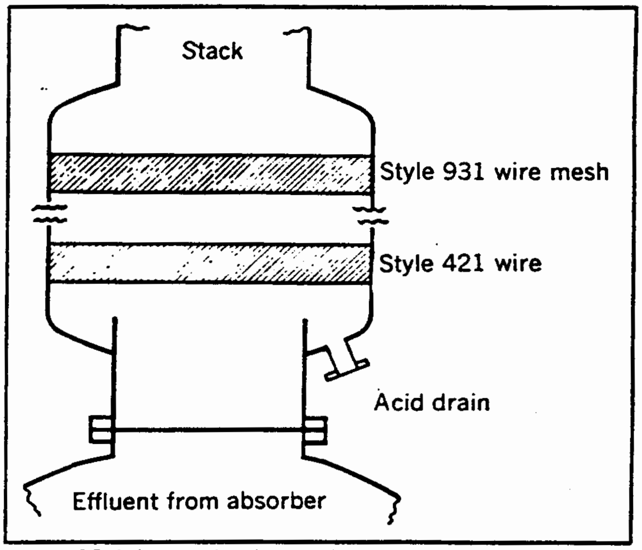

Figure 12. Wire mesh mist eliminator arrangement in vessel for installation above absorber in sulfuric acid plant.

particle size and amount are influenced by conditions particular to the individual plant, such as degree of operation control of absorbor acid concentration and temperature, acid recycle rate, presence of hydrocarbons in sulfur, and many other process variables. While the two-stage metal wire mesh arrangement as described by Massey (*12*) when properly operated, gives acceptable results, this arrangement has some disadvantages, mainly that to achieve good performance, the gas must be kept in a fairly limited velocity range. To give improved mesh efficiency over a broader gas velocity range, the composite mesh styles are used.

Large scale applications

Sea water evaporator: The fourth stage of a one-million gallon per day sea water evaporator, Figure 10, could not be operated at design boilup rates without greatly increasing salt content of condensate beyond the guarantee limits.

Flow conditions at the reduced rate were:

Evaporation rate—8300 gal./hr.
Pressure—3.5 in. Hg. abs.
Vapor velocity—22 ft./sec.
Liquor concentration—6-8% dissolved solids
Solids in condensate—50 ppm

Operation at the full rate of 10,500 gal./hr. resulted in increased condensate contamination to more than 200 ppm total solids. Even blending with the product of the first three evaporator stages placed the over-all purity above the guarantee level of 50 ppm.

A 6-in. thick Monel wire mesh mist eliminator with grids was installed 2 ft. above the liquid level in the vapor space of the fourth stage. Total solids in the condensate were reduced from 200 ppm to less than 8 ppm at full vapor rate. Ultimate capacity of the fourth stage equipped with the wire mesh was determined to be about 14,500 gal./hr. at which point condensate purity exceeded 20 ppm. Subsequent pilot testing showed that condensate purity as low as 0.2 ppm solids is possible from a sea water evaporator using greater mesh thickness.

Boiler feed water evaporator: A 3000 gal./hr. water evaporator shown in Figure 11 was producing condensate containing 1 ppm solids with a shell side concentration of 3500 ppm. Scaling in the boiler led to premature tube failure. Silica deposits on turbine blades caused frequent shutdowns. Correction of these difficulties was effected after installation of a 10-in. thick, 42-in. diameter wire mesh eliminator in place of the existing centrifugal unit. Condensate purity obtained using the wire mesh was less than 0.02 ppm total solids.

Sulfuric acid absorbor: As reported by O. D. Massey (*12*) wire mesh arranged as shown in Figure 12 has reduced sulfuric acid mist in absorbor stack gas to 1.0 mg./cu. ft. At the outlet mist loadings shown in Table 1, stack emission is practically invisible.

Sulfuric acid mist removal with composite meshes: A conventional two-stage Massey-type mist eliminator installed after a sulfuric acid absorber was giving good results, but the owner wanted wider operating range, and further wished to eliminate last traces of visible mist leaving the stack. A composite mist eliminator was installed. The superiority of the new installation is shown in Table 2. The stack remains invisible over the range shown and exceeds the performance of the wire mesh type.

Oil mist removal from ammonia synthesis gas: A serious carryover of lube oil mist in synthesis gas at 5600 lb./sq. in. gauge delivered from reciprocating compressors, was contaminating the catalyst in the ammonia reactors. To correct this difficulty a composite mist eliminator was installed in the existing separator vessel after existing vane-type eliminators were removed. When operation was resumed, 1 to 2 qt. of oil/day were drained from the vessel whereas a negligible quantity had been previously collected. The previous operating difficulties were eliminated entirely.

Recovery of precious metals: Entrained liquid carrying platinum and palladium in solution constituted a serious product loss in a precious metals reclaiming process. The metals could not be recovered since they were dissolved in highly corrosive acids which would destroy any of the standard metallic mist eliminators available. A Teflon mist eliminator installed in the vapor duct carrying the corrosive mist effected a high precentage recovery of the valuable metals. Separation efficiency of the Teflon mist eliminator is better than 99%, and there is no deterioration of the mesh despite contact with boiling aqua regia, nitric, sulfuric, and hydrochloric acids. #


York


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Edward W. Poppele received his B.Ch.E. from Cornell University in 1949, and, in 1958, a M.S. degree in chemical engineering from Newark College of Engineering. He joined the Otto H. York Co., Inc. in 1952, and is now sales manager for Demister mist eliminators. He is a registered professional engineer in New Jersey.

Notation

a—specific surface area, sq. ft./cu. ft.
f_c—friction factor from Figure 5, dimensionless.
g_c—gravitational constant 32.2 lb_m.-ft./lb_f.-sec^2.
G—gas mass flow rate, lb./hr., sq. ft.
K—a constant for calculating allowable gas velocity in Equation 5, ft./sec.
l—wire mesh thickness, ft.
L—liquid mass flow rate, lb./hr.-sq. ft.
ΔP—pressure drop across wire mesh without entrainment load, lb./sq. ft.
Δp_D—pressure drop, across wire mesh without entrainment load, in. of water.
Δp_L—pressure drop contributed by liquid load, Figure 6 and 7, in. of water.
Δp_T—pressure drop total across wire mesh with entrainment load, in. of water.
Re—Reynolds number defined by Equation 2, dimensionless.
U—superficial gas velocity, ft./sec.

Greek letters

ϵ—void fraction of wire mesh.
ρ_G—gas density, lb./cu. ft.
ρ_L—liquid density, lb./cu. ft.
μ—viscosity, lb./ft. sec. in Equation 2.
μ'_L—liquid viscosity, centipoises, in Figure 8.

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