

SEPARATORS, DRUMS, & MESH BLANKETS

Dae Oct. 18. 1944
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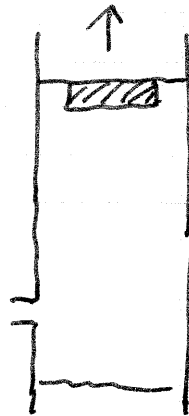
MIST ELIMINATOR

USED FOR ENHANCING SEPARATION
of

1. Liquid Droplets from Vapor
2. Liquid from Liquid

Advantage of Mist eliminators

Mist eliminators allow higher vapor velocities and therefore smaller equipment size by forming larger droplets that can more easily gravity settle.



How does entrainment occur

Entrainment of liq droplets of varying size and quantity in a gas occur

1. Whenever Gas contacts a liquid
2. When Liquid condenses from a gas.
- 3.

THEORY

1. Droplets contact wire surface
2. Droplets gather at wire intersection
3. " coalesce and grow in size
4. As droplets increase in size they drop lower in the mesh
- 5.
- 6.
- 7.

Mechanisms that cause entrainment.

1. Mechanical
2. Condensation.

TYPICAL OF IMPINGEMENT SEPARATORS

1. Staggered baffles on channels
2. Perforated plates
3. Fiber bed
4. Mesh blankets

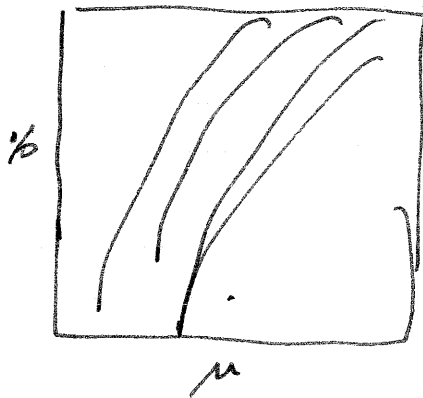


Fig. 2.
Yong-Fiberbed

CAPTURE MECHANISM

1. ~~Intercept~~ Inertial Impaction
2. Direct interception (Surface attraction)
3. Brownian capture : Random molecule motion.

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WHY ARE MIST ELIMINATORS USED?

1. Reduce loss of valuable product
2. Increase throughput capacity
3. high product purity.
4. eliminate contamination
5. Stop downstream corrosion
6. prevent air pollution.

Factors Governing Allowable Gas Velocity

1. Gas & liq. density
- 2.

ENGINEERING DESIGN SEMINAR

SEPTEMBER 6, 1994 – NOVEMBER 11, 1994

SEPARATORS, DRUMS, AND RECEIVERS

SCOPE

This section of the UOP Design Engineering Seminar will review design principles and provide process design guidelines for sizing most of the vessels used in UOP process units for phase separation, mixing and pressurized liquid surge and storage. Fractionators and reactors are the subjects of other sections and they are excluded from this scope.

SELECTION OF DESIGN PRESSURE

Up to 1000 psig (70.4 kg/cm²g), the design pressure is a minimum of 25 psi (1.8 kg/cm²) or 10 percent, whichever is greater, above the maximum operating pressure. For operating pressures above 1000 psig (70.4 kg/cm²g), the design pressure is a minimum of 100 psi (7.0 kg/cm²) or 5 percent, whichever is greater, above the maximum operating pressure. The reduced margin above 1000 psig (70.4 kg/cm²g) is taken in conjunction with the use of a pilot operated relief valve. If a pilot operated relief valve is not allowed, UOP practice calls for the margin to remain at 10 percent. The minimum design pressure for vessels is normally 50 psig (3.5 kg/cm²g).

Vessels will be specified for an external pressure of 15 psig (1 bar or 1 kg/cm²g) or full vacuum if the vessel normally operates under vacuum conditions, if the vessel can be subject to vacuum during normal or alternate operations (such as reactor circuit evacuation and purging or isolation of a liquid full vessel), or if the vessel can be subject to vacuum conditions due to equipment failure (such as loss of heat to a reboiler).

SELECTION OF DESIGN TEMPERATURE

The design temperature of process equipment is a minimum of 50 °F (28 °C) above the normal operating temperature, or 250 °F (120 °C), whichever is higher. When caustic is present, the latter temperature is limited to 150 °F (66 °C). For cryogenic applications, the design temperature is set at a minimum of 25 °F (14 °C) below the normal operating temperature. The selected design temperature should be reviewed for its effect on metallurgy selection, flange ratings, impact testing, and for any process exceptions.

The ASME Code requires that the Minimum Design Metal Temperature (MDMT) be specified. The MDMT will be the lowest of the normal operating temperature minus 25°F (14°C), the lowest 24 hour mean ambient temperature, or the result of an auto-refrigeration calculation based upon the process fluid.

SIZING CONSIDERATIONS

Vessel Configuration

The selection of a vessel configuration should consider space restrictions, economics and the following process requirements:

For a service with a high vapor rate, a low liquid rate and only one liquid phase, a vertical vessel is the most suitable to make efficient use of the cross-sectional area for vapor flow.

For a service with a low vapor rate, a high liquid rate and only one liquid phase, either a vertical or horizontal vessel is suitable although the horizontal vessel is usually preferred for ease of phase separation.

For a service with no vapor phase and two liquid phases, a horizontal vessel is the most suitable for ease of separation of the liquid phases.

For a service with a vapor phase and two liquid phases where the heavy liquid phase rate is small compared to the light liquid phase rate, a horizontal vessel with a drop leg is the most suitable.

For a service with a vapor phase and two liquid phases where the light liquid phase rate is small compared to the heavy liquid phase rate, a horizontal vessel with a baffled outlet end for the heavy liquid phase and an elevated compartment for the light phase is the most suitable.

For a service with a vapor phase and two liquid phases where the liquid phase rates are approximately equal, a horizontal vessel with a baffled outlet end for each of the liquid phases is the most suitable.

For horizontal vessels, tangent length/diameter (L/D) ratios should be determined. The L/D ratio of 3 results in the most economical vessel shell design and is the most commonly used ratio.

Residence Time

The determination of a residence time for the liquid phase should consider the following factors:

A recommendation based on experience with the process.

The effects of loss of level or over filling on upstream or downstream equipment.

The difficulty in separating phases. Fluid properties, emulsifying or foaming tendencies, upstream mixing, surface active agents and suspended solids can affect phase separation in varying degrees.

Common residence times used for sizing vessels are as follows:

For a horizontal vessel with a vapor phase and one liquid phase, 5 minutes based on the liquid phase rate, $\frac{1}{2}$ full, is usually adequate.

For a horizontal vessel with a vapor phase and two liquid phases, 10 minutes based on the total liquid rate, $\frac{1}{2}$ full, is usually suitable for most conditions. When the difference in densities of the liquid phases is low (7 lb/ft³ or less) and/or the lighter liquid viscosity is high (1 centipoise or more), 30 minutes or more may be necessary. When the difference in densities of the liquid phases is high (14 lb/ft³ or more), 5 minutes may be adequate. Experience with the system is especially important in liquid/liquid separations.

For liquid surge time from high to low level, 2 to 4 minutes is normally adequate for most conditions. For vertical separators upstream of compressors or other critical equipment, a minimum of two minutes surge time is provided between the bottom of the inlet nozzle and the maximum controlled level (HLL). For horizontal vessels, consideration should be given to the location of the normal

liquid level. If the vapor rate is small and the liquid rate is large, it may be advantageous to set the normal liquid level above the vessel center line to maximize the liquid residence time. Conversely, if the vapor rate is large and the liquid rate small, it may be advantageous to set the normal liquid level below the vessel center line to minimize the vapor velocity.

For drop legs with a level controlled outlet, 5 to 10 minutes is a suitable range for the drop leg capacity.

For drop legs with a manually controlled outlet, 600 minutes of drop leg capacity is adequate for one draining during an eight hour shift.

Phase Separation

Designing for phase separation assumes that a particle falling under the influence of gravity will accelerate until the frictional drag force balances the gravitational force. The particle then falls at a constant velocity which is defined as the terminal or free settling velocity. There are three laws for determining the terminal velocity which is the basis of criteria for sizing vessels for phase separation. These laws have limits based on the particle Reynolds number as follows:

Particle Reynolds No.	Law	Terminal Velocity Equation
< 2	Stokes'	$\frac{(\rho_P - \rho)gD_P^2}{18\mu}$
2 to < 500	Intermediate	$\frac{0.153g^{0.71}D_P^{1.14}(\rho_P - \rho)^{0.71}}{\rho^{0.29}\mu^{0.43}}$
500 to < 200,000	Newton's	$1.75\left[\frac{gD_P(\rho_P - \rho)}{\rho}\right]^{0.5}$

The terms in these equations are as follows:

ρ = density of the continuous phase

ρ_P = density of the particle

D_P = diameter of the particle

μ = viscosity of the continuous phase

g = gravitational constant

Design conditions for receivers, separators and drums fall into the categories of the Stokes and Intermediate Laws. Stokes' Law is used for disentraining vapor from the liquid phase and gravity settling the dispersed liquid phase from the continuous liquid phase, and the Intermediate Law is used for gravity settling liquid from the vapor phase. The particle size or diameter used in these laws is often difficult to determine. In selecting the particle diameter, the effect of entrainment on downstream equipment, effluent quality and overall economics should be considered.

The following particle diameters are used in these guidelines in lieu of more definitive sizes:

250 microns for gravity settling liquid from the vapor phase.

175 microns for disentraining vapor from the liquid phase.

125 microns for gravity settling the dispersed liquid phase from the continuous liquid phase.

GUIDELINES FOR SIZING VERTICAL VESSELS

Surge/Storage Vessels

Determine the tangent length/diameter (L/D) ratio.

Determine the liquid residence time required and percent liquid full at normal liquid level.

Calculate the liquid holdup volume required to satisfy the liquid residence time. This is the volumetric liquid flowrate, Q_L , multiplied by the liquid residence time, T .

$$V_L = Q_L T$$

Calculate the volume of the vessel, V_V . This is simply the liquid volume, V_L , divided by the percent liquid full, F .

$$V_V = V_L / F$$

Since the volume of the vessel equals the volume of a cylinder, set the vessel volume, V_V , equal to the volume of a cylinder.

$$V_V = \frac{\pi D^2 L}{4}$$

Substitute for the L/D ratio and solve for the vessel diameter, D . For an L/D ratio of 3, the equation is as follows:

$$V_V = \frac{\pi D^2 (3D)}{4}$$

$$\text{and } D = \left[\frac{4V_V}{3\pi} \right]^{1/3}$$

Round off diameters and tangent lengths to the next larger standard increment.
UOP uses 6 inch English and 100 millimeters Metric increments.

Surge/Storage Sizing Example

Size a feed surge drum for a Tatoray Unit. The feed rate is $20.39 \text{ m}^3/\text{h}$.

Select an L/D of 3.

Size vessel for 30 minutes liquid residence time at 75 percent liquid full.

Calculate the liquid holdup volume.

$$V_L = Q_L t = (20.39 \text{ m}^3/\text{h})(0.5 \text{ h}) = 10.2 \text{ m}^3$$

Calculate the volume of the vessel.

$$V_V = V_L / F = 10.2 \text{ m}^3 / 0.75 = 13.6 \text{ m}^3$$

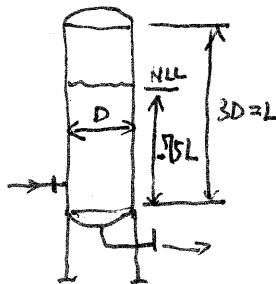
Set the volume of the vessel equal to the volume of a cylinder whose L/D is 3 and solve for D . (IGNORE HEAD VOLUME)

$$V_{Cyl} = \pi D^2 L / 4 = 3 \pi D^3 / 4 = 13.6 \text{ m}^3$$

$$D = 1.79 \text{ m}$$

$$\text{so } L = 3D = 5.38 \text{ m}$$

Convert to millimeters and round to 1800 millimeters inside diameter and 5400 millimeters tangent length.



Phase Separation Vessels Without Demisting Blanket

Our method will be to size the vessel diameter so that the vapor velocity is equal to or less than the terminal velocity of a liquid droplet falling through the continuous vapor phase. The liquid velocity must also be equal to or less than the terminal velocity of a bubble rising through the continuous liquid phase. Refer to Appendix 1 for a sketch of the system and a definition of terms. Subscripts DL and CV refer to the dispersed liquid and continuous vapor phases.

Calculate the terminal velocity of the liquid droplet, V_{DL} , using the Intermediate equation.

$$V_{DL} = \frac{0.153 g^{0.71} D_{PL}^{1.14} (\rho_L - \rho_V)^{0.71}}{\rho_V^{0.29} \mu_V^{0.43}}$$

The vapor velocity rising in the vessel, V_{CV} , is equal to the vapor volumetric flowrate, Q_{CV} , divided by the vessel cross-sectional area, and the cross-sectional area is the area of a circle with diameter D .

$$V_{CV} = \frac{Q_{CV}}{A} = \frac{4Q_{CV}}{\pi D^2} = V_{DL}$$

Substitute for V_{DL} and solve for D .

$$D = 2.9 \left[\frac{Q_V \rho_V^{0.29} \mu_V^{0.43}}{g^{0.71} D^{1.14} (\rho_L - \rho_V)^{0.71}} \right]^{0.5} \quad (1)$$

Similarly, the terminal velocity of the bubble rising through the continuous liquid phase can be calculated using Stokes' equation.

$$V_{DV} = \frac{g D_P^2 (\rho_L - \rho_V)}{18 \mu}$$

The liquid velocity flowing downward in the vessel, V_{CL} , is equal to the liquid volumetric flowrate, Q_L , divided by the vessel cross-sectional area, and the cross-sectional area is that of a circle with diameter D .

$$V_{CL} = \frac{Q_L}{A} = \frac{4Q_L}{\pi D^2} = V_{DV}$$

Substitute for V_{DV} and solve for D .

$$D = 0.23 \left[\frac{Q_L \mu_L}{g D_{PV}^2 (\rho_L \rho_V)} \right]^{0.5} \quad (2)$$

Based on the largest calculated vessel diameter from 1 and 2 above, determine whether an ellipsoidal or a flanged flat top head is suitable. Vessels smaller than 30 inches (750 millimeters) in diameter should have a flanged flat top head. Vessels with a diameter of 30 inches (750–800 millimeters) can have either type of top head. Vessels larger than 30 inches (800 millimeters) in diameter should have an ellipsoidal top head.

Determine the liquid level range for the vessel based on residence time considerations.

Calculate the vessel tangent length based on the type of top head, the liquid level range and any necessary surge time above the maximum controlled level (HLL) by using the equations in the sketches in Appendix 1.

Round off diameters and tangent lengths to the next larger standard increment. UOP uses 6 inch English and 100 millimeters metric increments.

Phase Separation Vessels With a Demisting Blanket

Placement of a demisting mesh blanket is defined by the equations and sketches in Appendix 1. Actual sizing of the demisting mesh blanket is covered in a separate presentation.

If vapor/liquid/liquid phase separations are required except for baffled separators, calculate the diameters for the necessary phase separations. Proceed for vapor/liquid separation as follows:

Determine the terminal velocity, V_{DL} , of the droplet using the Intermediate equation.

$$V_{DL} = \frac{0.153 g^{0.71} D_{PL}^{1.14} (\rho_L - \rho_V)^{0.71}}{\rho_V^{0.29} \mu_V^{0.43}}$$

The maximum distance the droplet must fall is the height of the vapor space, from the top of the drum to the maximum liquid level. Let this distance be XD , where X is the vapor space height expressed as a fraction of D . The time, T , to drop through the vapor space is:

$$T = XD/V_{DL}$$

The velocity of the vapor through the vessel, V_{CV} , is the volumetric flow rate of the vapor, Q_{CV} , divided by the flow area, where the flow area is expressed as a fraction, Z , of the vessel cross sectional area, $0.785D^2$.

$$V_{CV} = \frac{Q_{CV}}{Z(0.785D^2)}$$

The time for the vapor to pass through the vessel is simply the distance between inlet and outlet nozzles divided by the vapor velocity. We can express this distance as a factor, Y , times the diameter, D , where Y is $(L/D)-1$ if we assume that the inlet and outlet nozzles are each a maximum $0.5D$ from the vessel tangent. Now if the time for the droplet to fall is set equal to the time for the vapor to pass through the vessel, we have:

$$T = \frac{XD}{V_{DL}} = \frac{YD}{V_{CV}}$$

GUIDELINES FOR SIZING HORIZONTAL VESSELS

Vessel Shell

Phase separation in a horizontal vessel should account for the fact that the forces acting on the particle to be separated are not acting in the same plane. The gravity/buoyant forces are acting in a vertical direction but the continuous fluid movement, and thus the drag forces, are acting in a horizontal direction. Our method takes into consideration the direction of these forces as well as the vessel geometry in determining the vessel size.

Focus on the separation of a liquid droplet from a continuous vapor phase. Refer to Appendix 2 for a sketch of the system and a definition of terms. The droplet must fall through the vertical distance of the vapor space to the continuous liquid phase before the horizontal forces of the vapor carry the droplet out of the vessel. To assure that the separation is maintained at all operating conditions, we will investigate the separation when the liquid level is at its highest. The highest liquid level will be no more than 0.25 diameter above the centerline.

Select the tangent length/diameter (L/D) ratio.

Determine the liquid residence time required and percent liquid full at normal liquid level. The normal liquid level is usually at the centerline, but exceptions can be considered.

Determine the normal liquid level (NLL) for vessels not liquid full. See Appendix 3 for NLL locations and related cross-sectional areas, allowable level ranges and residence times. A standard level control range should be selected as close as possible to the allowable level range indicated in Appendix 3 for the NLL used for design.

Calculate the vessel diameter to satisfy the residence time.

Substitute for V_{DL} , V_{CV} , and Y and solve for D .

$$D = \left[\frac{X}{0.785(0.153)YZ} \right]^{0.5} \left[\frac{Q_{CV} \rho_V^{0.29} \mu_V^{0.43}}{g^{0.71} D_{PL}^{1.14} (\rho_L - \rho_V)^{0.71}} \right]^{0.5}$$

If X is 0.25, then Z is 0.20 and if we selected an L/D of 3, then Y is 2. The equation then simplifies to:

$$D = 2.28 \left[\frac{Q_{CV} \rho_V^{0.29} \mu_V^{0.43}}{g^{0.71} D_{PL}^{1.14} (\rho_L - \rho_V)^{0.71}} \right]^{0.5}$$

Using a similar analysis, the vessel diameter can be calculated for separation of a vapor bubble from the continuous liquid phase. For this, Stokes' equation must be used in place of the Intermediate equation.

If liquid/liquid separation is required, the calculation of the vessel diameter proceeds as in the paragraph above using the properties of the two liquid phases in Stokes' equation.

If a vertical coalescing mesh blanket is to be installed in the vessel, calculate the diameter necessary for a maximum liquid velocity of 3 ft/m. The clearance between the mesh blanket and the drop leg should be approximately one-half of the vessel diameter.

Size the vessel on the basis of the largest of the preceding calculated diameters.

Round off diameters and tangent lengths to the next larger standard increment.

Vessel Drop Leg

Determine the residence time.

Calculate the drop leg diameter for phase separation by using Stokes' equation.

If the process specialist has recommended a maximum drop leg velocity, calculate the drop leg diameter by using that maximum velocity.

Calculate the drop leg diameter based on the residence time and a drop leg length of 3.5 feet (1070 millimeters).

If the largest of the preceding calculated drop leg diameters is less than one-half of the vessel diameter, round this diameter to the next larger whole even inch increment to match pipe diameters. If the largest of the preceding calculated drop leg diameters is equal to or larger than one-half of the vessel diameter, round one-half of the vessel diameter down to the next lower whole even inch increment and increase the drop leg length beyond 3.5 feet (1070 millimeters) to satisfy the residence time requirement and round the length to the next largest 3 inch (100 millimeters) increment. If the drop leg length becomes larger than 6 feet (1800 millimeters), a smaller residence time or a different vessel configuration, such as a baffled separator, should be considered.

Drop leg diameters should be specified as OD (outside diameter). The minimum drop leg outside diameter is 14 inches (360 millimeters). The minimum drop leg length is 3.5 feet (1070 millimeters).

Horizontal Vessel Sizing Example

Refer to Appendix 4 for an example of the method for sizing a horizontal vessel for vapor/liquid/liquid separation.

VESSEL NOZZLES

Connections on pressure vessels are normally flanged. Nominal 3000lb coupling connections are commonly used for 1 inch and smaller connections on atmospheric or non-code vessels. Such connections are however more susceptible to corrosion and should not be used in a corrosive environment.

Minimum Size

UOP practice requires a minimum nozzle size of 1 inch on pressure vessels. This ensures mechanical strength and reduces the chance of plugging of the nozzle. Sometimes customers request a larger minimum nozzle size on vessels, e.g. $1\frac{1}{2}$ inches or 2 inches. This requirement is shown in the BEDQ, Section VII. B. Vessels. There are other minimum size requirements for certain services such as vents, drains, steamout, level, temperature, and manways which will be discussed later.

Oversized Nozzles

Oversized nozzles on vessels are at times required for reasons such as those shown below:

For stab-in distributors, collectors and drain screens.

For internal insulation or lining of a nozzle.

A 2 inch nozzle size should be used when instruments are connected to a lined vessel. Special level instrument connection sizes can be as large as 3 inch.

Use of a PSV with a $2\frac{1}{2}$ inch inlet flange. This requires a 3 inch vessel nozzle.

To reduce the velocity of a mixed phase to the inlet of a horizontal vessel.

The oversized nozzle size will be shown on the P&ID to confirm that it is intentionally larger than the connecting line size.

Maximum Size

Nozzles larger than half the vessel diameter require additional investigation and possibly additional reinforcement and are not normally recommended by UOP.

Nozzles On Vessel Heads

According to the ASME Section VIII Pressure Vessel Code, all nozzles on vessel heads must be located inside a circle of diameter 0.8 times the inside diameter of the vessel. On very small fractionators, it is sometimes necessary to install the vapor outlet on the side rather than on the head to satisfy this requirement. Consult a flange table for the outside diameter of flanges.

Nozzle Location Limitations

Vessel Weld Line

To avoid interference with the vessel weld line, 2 inch nozzles and smaller are normally located with a minimum of 6 inches (150 millimeters) from the tangent line to the centerline of the nozzle. Nozzles greater than 2 inches should be located a minimum distance of the nozzle diameter plus 5 inches from the tangent line to allow for the reinforcing pad.

Tangential Nozzles

Generally, for tangential nozzles on horizontal vessels, the maximum permissible distance from the centerline of the vessel to the nozzle is 0.45 times the vessel diameter for diameters greater than 12 feet. For more information and a table of maximum permissible distances versus vessel diameters refer to Appendix 5.

Manways

UOP practice is to specify manway sizes as inside diameter and to provide a minimum manway size of 18 inch inside diameter, including lining, if applicable. Larger size manways should be specified if required to accommodate internals. Nominal sized manways are specified only upon Owner request.

Horizontal Vessels

On unlined horizontal vessels, the manway should normally be located on the side of the vessel at or below the horizontal center line. If the bottom half of the horizontal vessel is lined, the manway will be located on the upper side or the top of the vessel. Horizontal vessels with a diameter of 2 feet–6 inches or less can have a full flanged head.

Vertical Driers, Treaters etc.

These vessels usually combine the top manway with the process piping and also use it for loading solids or packing. The size should be a minimum of 18 inches inside diameter and may be larger to permit installation of internals. A manway is provided on some driers or clay towers on the side near the bottom of the vessel to unload solids directly into a truck.

Removable Internals

The manway on a vessel with removable internals should be sized to accommodate the largest section (pipe fitting, etc.), of the internals. Refer to Appendix 6, Minimum Openings Required for Pipe Fittings. For example suppose a 14 inch straight tee had to fit through the manway of a column. Appendix 6 shows the minimum opening required is 21 inches. A manway size of 24 inches would be selected since 22 inch manways are not used. Reactors also require large manways to accommodate centerpipes, etc.

The inside diameter of a nominal sized manway depends on nozzle construction, corrosion allowance, and code requirements. Generally, manways with Class 150 or 300 flanges in the nominal size range of 18 to 24 inches have an inside diameter about 1 inch less than the nominal size. Higher flange classes and larger sizes require that the inside diameter be specified.

Inspection Openings

These guidelines apply to vertical vessels in pressure service with diameters of 3 feet–6 inches (1100 millimeters) and less. The minimum allowable inspection openings are defined in the ASME Code Section VIII.

Vessels with an inside diameter of 12 inches or Less

No separate inspection openings are required if there are at least two removable pipe connections of a size not less than $1\frac{1}{2}$ inches located at each end of the vessel on the head or on the shell near the head. If separate inspection openings are required, $1\frac{1}{2}$ inch flanged connections should be provided, as described in the previous sentence.

Vessels with an inside diameter 16 inches or less but greater than 12 inches

Vessels with removable internals have a flanged top head and one $1\frac{1}{2}$ inches inspection opening on or near the bottom head. Vessels without removable internals have the same inspection openings as described under Oversized Nozzles on page 14.

Vessels with an inside diameter of 18 inches through 24 inches

These vessels have a flanged top head.

Vessels with an inside diameter of 2 feet–6 inches (760 millimeters)

Vessels with removable internals can have a flanged top head or an elliptical head with a manway on or near the head. Vessels without removable internals have a manway located on the shell near the bottom head.

Vessels with an inside diameter of 3 feet–0 inches (900 millimeters) and 3 feet–6 inches (1100 millimeters)

These vessels are specified with a manway.

Ventilation

Horizontal vessels 10 feet (3000 millimeters) and greater in tangent length are provided with a blanked off ventilation nozzle on top of the vessel near the end opposite the manway. This nozzle is a standard safety item necessary for the preparation of the vessel for safe entry. It cannot be omitted upon customer request. The ventilation nozzle is sized as follows:

Vessel Tangent Length	Nozzle Size
10 feet–0 inches (3000 mm) through 15 feet–0 inches (4500 mm)	4 inches
Over 15 feet–0 inches (4500 mm) through 25 feet–0 inches (7500 mm)	6 inches
Over 25 feet–0 inches (7500 mm)	8 inches

Refer to Appendix 7, Location of Manway Versus Ventilation Nozzle, to determine appropriate locations.

Steamout

A steamout connection will be provided on each vessel which is steamed out as part of the normal start-up or shutdown operation. Examples of vessels which **will not** be provided a steamout connection are reactors in hydrogen-rich gas circuits, vessels containing caustic, and vessels containing materials such as molecular sieves which could be damaged by water.

The steamout nozzle size will be the same as the vent with a minimum size of 2 inches. A 2 inch connection will be fitted with a gate valve and blankoff. When the steamout connection is 3 or 4 inches, the steamout connection will be hard piped with a gate valve, spectacle blind, $\frac{3}{4}$ inch plugged bleed valve, check valve, and gate valve. The steamout connection will be located near the bottom head on vertical vessels and on the head furthest from the ventilation nozzle on horizontal vessels.

Vents And Drains

The UOP practice for minimum sizes of vents and drains is shown below. A check should be made to determine whether any process reasons or Owner instructions exist which would require vents or drains to be sized differently from these minimum sizes.

Vessel Diameter	Vent and Drain Size
15 feet-0 inches (4500 mm) and less	2 inches
Over 15 feet-0 inches (4500 mm) through 20 feet-0 inches (6000 mm)	3 inches
Over 20 feet-0 inches (6000 mm)	4 inches

Vent and drain nozzles are the same size.

In general, with the exception of some reactor systems in hydrogen service, all vessels should have a vent and drain

For vertical vessels, the atmospheric vent nozzle and valve are located on the vessel, or on piping near the vessel, at the highest point and are used for venting to atmosphere, for steam out, purging, and hydrostatic testing.

For horizontal vessels, the atmospheric vent valve is located on the vessel with a vent valve to atmosphere.

When a steamout connection is specified, the vent nozzle is located on the vessel with a vent valve to atmosphere.

The vent valve to atmosphere is not required when there is no steam out connection, or when a vessel is purged and evacuated.

A depressuring connection to the pressure relief header is always required.

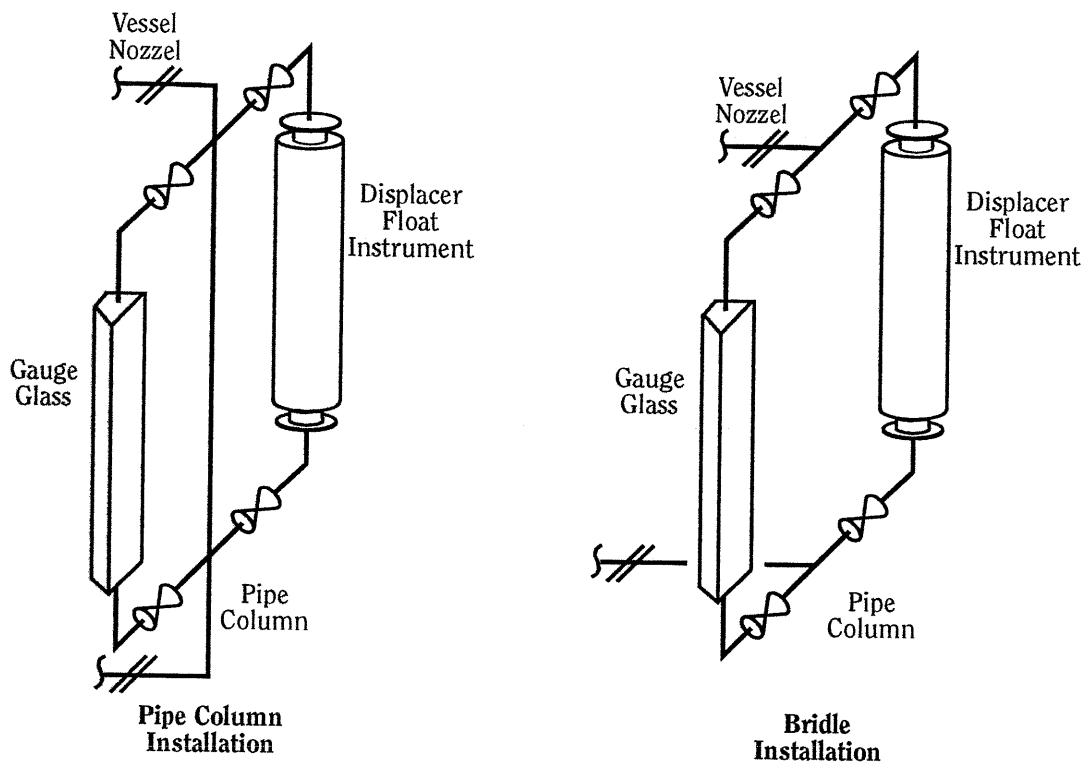
The drain is located on the vessel or on piping near the vessel at the lowest point for draining hydrostatic test water to the sewer or hydrocarbon to a closed drain or pumpout system.

Unloading

Withdrawal nozzles are installed at an angle on the bottom head of radial flow reactors and treaters and at an angle on the side and /or bottom head of most downflow reactors and treaters.

Instrument/Gauge Glass

Displacer float instruments and gauge glasses may be installed with separate connections to the vessel. When they occur together, they may be installed in bridge or pipe column installations as shown below:



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The choice between a bridge or pipe column depends upon a number of factors. Due to equipment limits and consideration for piping rigidity and differential thermal expansion between the vessel and the instrument installation, length limits are observed as indicated.

Arrangements and Nozzles for Displacer Float Instruments and Gauge Glasses					
		Displacer Float Instruments		Gauge Glasses	
	Maximum Span Between Vessel Nozzles	Minimum Vessel Nozzle Size	Maximum Float Length	Minimum Vessel Nozzle Size	Maximum Nominal Length
Separate Connections	15 ft-0 in (4600 mm)	1-1/2 in	10 ft-0 in (3048 mm)	1 in	5 ft-6 in (1650 mm)
Bridle Installation	9 ft-0 in (2700 mm)	1-1/2 in	5 ft-0 in (1524 mm)	1-1/2 in	5 ft-6 in (1650 mm)
Pipe Column Installation	15 ft-0 in (4600 mm)	2 in	10 ft-0 in (3048 mm)	2 in	5 ft-6 in (1650 mm)

For information on standard sizes of level and gauge glasses refer to Appendix 8.

Thermowell nozzles must be flanged and specified as 1 inch inside diameter minimum.

Pressure Relief Valves

When pressure relief valves (PSV's) are connected to a vessel, UOP calls for the nozzle size to have an inside diameter the same size as the PSV inlet flange unless the inlet piping to the PSV is oversized to avoid excessive pressure drop. The nozzle on the vessel has a minimum flange rating of ANSI Class 300.

Drop Leg

Liquid drop legs (sometimes referred to as "boots") are provided on horizontal vessels as follows:

If the vessel is lined and the drop leg diameter is less than 30 inches, the drop leg will be unlined and flanged to the vessel.

If the vessel is lined and drop leg diameter is 30 inches or greater, the drop leg will be internally lined and welded to the vessel.

If the vessel is unlined, the drop leg will be unlined and will be welded to the vessel regardless of drop leg diameter.

Refractory Lined Vessels

Nozzles where the vapor flow will impact a refractory lined surface should be designed for a maximum velocity of 35 ft/s, especially in services with a high hydrogen content.

HORIZONTAL AND VERTICAL VESSEL INTERNALS

Coalescing Blankets

Coalescing blankets are used to coalesce fine droplets of the dispersed phase from the continuous phase in a shorter period of time than could be accomplished in an empty vessel.

Demisting Blankets

Demisting blankets are used to remove entrained liquid in vapor streams where such liquid could cause damage to down-stream equipment such as compressors or result in loss of product to the fuel system, etc. If excessive entrainment of liquid in the vapor outlet stream could be economically significant or detrimental to equipment, safety, or operation, the vessel is sized to allow gravity settling of liquid from the vapor phase in

addition to providing a partial mesh blanket. For less critical situations a full dimension demisting blanket which meets the vapor velocity criteria can be used.

Distributors

Please see Appendix 9 for UOP Standard Drawings and UOP drawings of Distributors.

Total Liquid Inlets to Horizontal Drums – Subcooled Liquids

For subcooled total liquid inlets such as cold feed surge drums or overhead systems with the final condenser at grade, the liquid inlet can be through the top of the vessel with an internal open end, non-slotted pipe (UOP Drawing No. C17057-B, Type B) or through the bottom of the vessel with a baffle (UOP Drawing No. C17059-B). In either case, the inlet nozzle and the internal distributor will be the same size as the line size to the vessel. The distributor should remain sealed under the minimum liquid level.

Total Liquid Inlets to Horizontal Drums – Bubble Point Liquids

For total liquid inlets where the possibility of small quantities of vapor may exist, such as a bubble point system, low pressure system, or overhead condensing systems with an equalizing line to the condenser rundown line, the inlet will be through the top of the vessel with an internal closed end, slotted pipe distributor (UOP Drawing No. C17057-B, Type C). The inlet nozzle and internal distributor pipe will be the same size as the line size to the vessel. The closed end will terminate 6 inches above the bottom of the vessel. The slotted area is approximately twice the cross sectional flow area of the distributor pipe and is provided by one slot, oriented on the vessel centerline, facing the nearest head of the vessel. The slotted section of the distributor starts approximately 6 inches from the top of the vessel and extends the length of distributor to the closed end. For small diameter distributor pipes, intermittent slots should be considered in preference to very narrow slots.

Total Liquid Inlets to Horizontal Drums – Two Immiscible Liquids

For total liquid systems with two immiscible liquids present in sufficient quantities to establish an interface level at or near the centerline of the vessel, not in a drop leg, the inlet will be on the side of the vessel with an internal distributor perpendicular to the major axis of the vessel (UOP Drawing No. C17058-A). The inlet nozzle and the internal distributor will be the same size as the line size to the vessel. The horizontal pipe will be located at the normal elevation of the interface between the two liquids and will be closed at the end opposite the inlet and slotted on the side opposite the vessel outlet. The length of the horizontal pipe should be great enough to permit a slot area approximately twice the cross sectional flow area of the distributor inlet pipe.

Mixed Phase Inlets to Horizontal Drums

Pipe lines carrying mixed phase streams are quite often sized for higher velocities than total liquid lines. If these higher velocities were carried into the vessel, the resulting turbulence would interfere with the disengaging function of the vessel. Therefore, both the inlet nozzle and the inlet distributor will be expanded one pipe size greater than the line size to the vessel in order to reduce the inlet velocity. The expanded inlet nozzle size must be indicated on the P&I Diagram to confirm that it is intentionally larger than the line size.

The inlet is located at the top of the vessel and will have a closed end, slotted internal distributor pipe terminating 6 inches above the bottom of the vessel (UOP Drawing No. C17057-B, Type C). The slotted area is between two and three times the cross sectional flow area of the distributor pipe. The slotted section of the distributor starts approximately 6 inches from the top of the vessel and extend the length of the distributor to the closed end. The slotted area for all vessels except those with a vapor phase and baffles for separate ends for light and heavy liquid phases is provided by one slot facing the nearest head of the vessel. For vessels with a vapor phase and baffles for separate ends for light and

heavy liquid phases, the slotted area is provided by two slots arranged perpendicular to the major axis of the vessel.

Vertical Drums

Vertical receivers or separators should use a tee type distributor located close to the vessel wall. Refer to UOP Standard Drawing 3-190. For small vessels with flanged top heads, the tee distributor is omitted.

Vortex Breakers

Please see Appendix 9 for UOP Standard Drawings of Vortex Breakers.

Bottom

Vortex breakers (VB's) are used in any vessel outlet nozzle from which a pump is taking suction. They are also used if gas entrainment would present a problem in downstream equipment to which an outlet is feeding. The standard VB is made of two plates forming a cross extending down into the nozzle and overlapping the nozzle above the outlet. The type of VB depends on the vessel lining if any, and on nozzle size. A raised VB always is provided if there is a drop leg on the vessel. The top of the extended pipe vortex breaker is 6 inches above the vessel shell unless there is a specific process reason to the contrary. See UOP Standard Drawing 3-122 and 3-123.

Side

For pump suction nozzles on the side of a vessel, or for very large nozzles, a grating is installed as a VB when the outlet is close to a liquid-vapor interface. See UOP Standard Drawing 3-322. A VB is **not** required for a fractionator tray drawoff nozzle.

ANCILLARIES

This section is concerned with ancillaries for both vertical and horizontal vessels.

Vessel Supports

Skirt

Most vertical vessels are supported by a skirt. The bottom nozzles must project through the skirt to avoid flanges inside the skirt, reducing the hazards associated with leaks.

For small vessels less than 3 feet–6 inches (1100 millimeters) in diameter, if the support length from the base of the support to the bottom tangent line is 5 feet–0 inches (1500 millimeters) or less, then support legs are provided. See UOP Standard Drawing 3-104. If the support length is greater than 5 feet–0 inches, then a vessel skirt is specified. Generally straight skirts are specified based on economics. There are exceptions for supports and good engineering judgement should be used.

Legs

Legs are sometimes used on short drums at low pressures to save cost and avoid flanges inside skirts. See above section for specific guidelines.

Lugs

Lugs are used for equipment support when good ventilation of the vessel surface is required, or a small diameter does not allow a skirt or legs to be provided.

Table Top

Table top support is used where access to the bottom of a vessel is required. It is the most expensive type of support and is generally avoided. The vessel can be supported on the table top with lugs or a short straight or flared skirt.

Saddles

Most horizontal vessels are supported on saddles which sit on concrete supports. Saddles are normally 6 inches to 10 inches wide and are located at a distance from the vessel tangent lines no greater than 0.25 times the vessel diameter.

Bracing

The criteria for deciding when bracing is required depends on the vessel length and diameter. The vessel length (L) to be considered is the distance from the bottom of skirt to the top of the top head. Vessels with high length to diameter ratio (L/D) need bracing to prevent excessive sway. For vessels up to 130 feet in length, bracing is required when L/D is greater than 20, and for vessels longer than 130 feet, the criterion is L/D greater than 15.

Stiffener And Insulation Rings

Stiffener Rings

Stiffener rings are made from angle irons, channels or tee sections and are used to strengthen vessels for vacuum service and external pressure requirements.

Insulation Rings

Insulation rings are used to support block insulation on the walls of vessels.

Fireproofing And Insulation

Fireproofing

Fireproofing is applied to all steel vessel supports at an elevation of 35 feet or less, located in an area with fire potential, which could cause overturning of the vessel from failure during a fire.

Insulation

Insulation is called for whenever heat loss or heat gain would affect the process. When insulation is required, the vessel project specification should indicate a requirement for insulation clips and rings. Insulation for personnel protection is left to the contractor and is not shown in UOP project specifications or drawings.

Weather Shielding

Weather shielding is sometimes provided to minimize thermal stress and differential thermal expansion of uninsulated nozzles and flanges.

Davits

Davits are a type of crane installed on fractionators and vessels to facilitate the raising of internals and for handling manway covers.

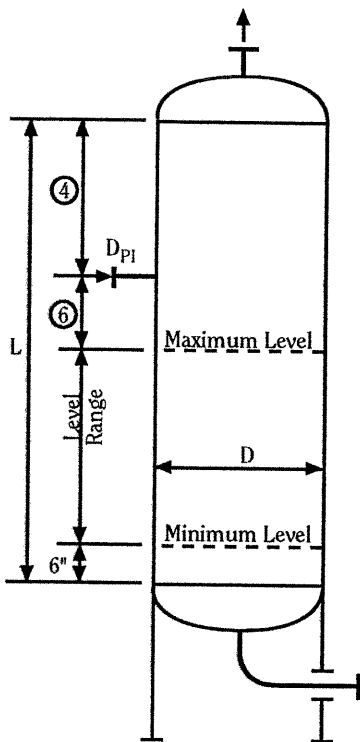
Platforms

Platforms are installed at all manways and wherever required to reach equipment, such as controls, more than about 8 feet above grade. The vessel project specification indicates that ladder and platform clips are to be provided as required by the contractor. UOP does not show specific platform requirements in its specifications.

APPENDIX 1

Phase Separation in Vertical Vessels

Vapor/Liquid Separation



A	Cross-sectional area, ft. ²
D	Vessel I.D., ft.
D _B	Diameter of mesh blanket, ft.
D _{PI}	Normal pipe diameter of inlet, in.
D _{PO}	Normal pipe diameter of outlet, in.
D _{PL}	Liquid particle diameter, ft. *(0.00082 ft.)
D _{PHL}	Heavy liquid particle diameter, ft. *(0.00041 ft.)
D _{PLL}	Light liquid particle diameter, ft. *(0.00041 ft.)
D _{PV}	Vapor particle diameter, ft. *(0.00057 ft.)
F	Percent liquid full
g	32.2 ft/s ²
L	Tangent length, ft.
Q _L	Flow rate of liquid phase, gpm
Q _V	Flow rate of liquid phase, ft ³ /s
t	Liquid residence time, minutes
ρ _L	Liquid density, lb/ft ³
ρ _{HL}	Heavy liquid density, lb/ft ³
ρ _{LL}	Light liquid density, lb/ft ³
ρ _V	Vapor density, lb/ft ³
μ _L	Liquid viscosity, lb/ft sec
μ _{HL}	Heavy liquid viscosity, lb/ft sec
μ _{LL}	Light liquid viscosity, lb/ft sec
μ _V	Vapor viscosity, lb/ft sec
*	Use in the absence of specific process data
③	0.4D _B (Min.)
④	0.5D _{PI} + 3'-0"
⑤	0.5D + 0.5D _{PI}
	>0.5D _{PI} + 2'-0" } limits
	<0.5D _{PI} + 4'-0" }
⑥	0.5D _{PI} + 1'-6" (Min.)

Note: Flowing data are at operating conditions.

EDS-R00-3421

Gravity settling liquid from vapor phase:

$$D = 2.9 \left[\frac{Q_V \rho_V^{0.29} \mu_V^{0.43}}{g^{0.71} D_{PL}^{1.14} (\rho_L - \rho_V)^{0.71}} \right]^{0.5}$$

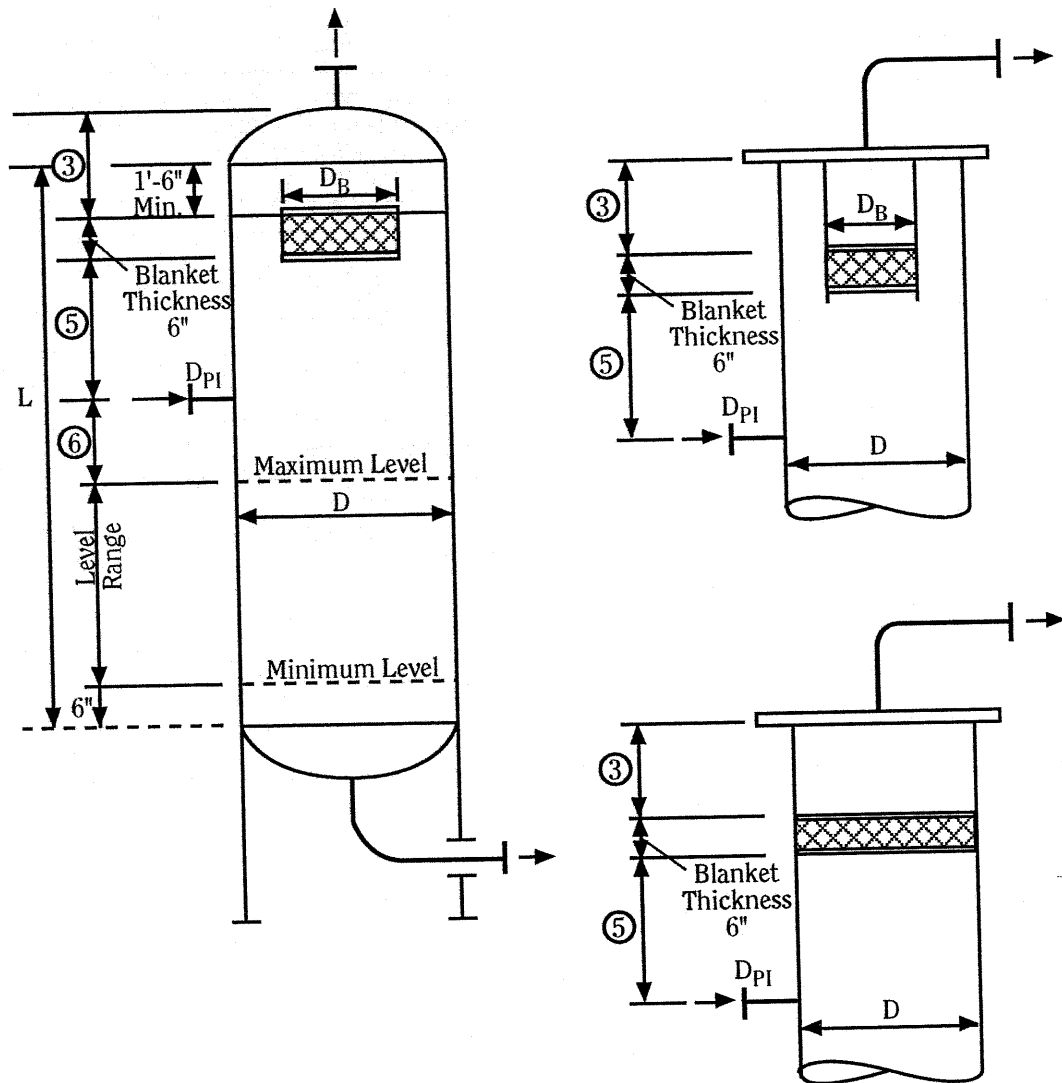
Disentraining vapor from liquid phase:

$$D = 0.23 \left[\frac{Q_L \mu_L}{g D_{PV}^2 (\rho_L - \rho_V)} \right]^{0.5}$$

APPENDIX 1 Continued

Phase Separation in Vertical Vessels

Vapor/Liquid Separation with Mesh Blanket Demisting



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FOR CRITICAL SERVICE

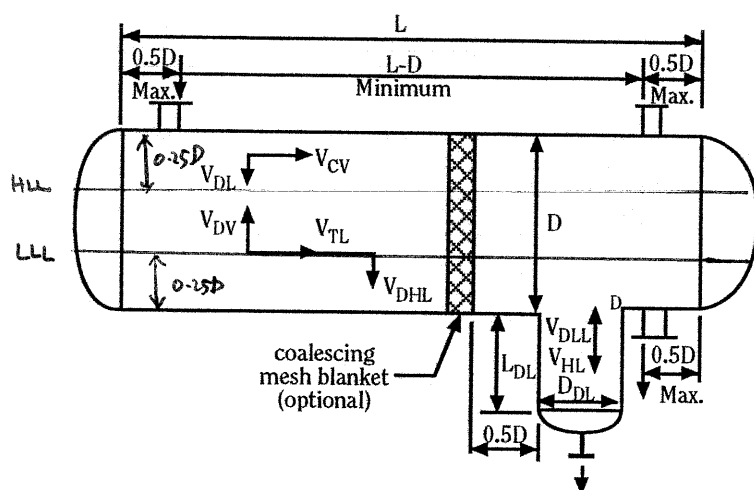
- VESSEL SIZED FOR GRAVITY SETTLING DROPLET
- MESH BLANKET SIZED FOR EFFICIENT COALESCING

APPENDIX 2

Phase Separation in Horizontal Vessels

Horizontal Vessels

Vessel dimensions based on vapor/liquid/liquid separation with drop leg.



Diameter for gravity setting liquid from vapor phase

D	Inside diameter, ft
D _{DL}	O.D. of drop leg, in
L	Tangent length, ft
L _{DL}	Length of drop leg, ft
V _{CV}	Velocity of continuous vapor phase, ft/s
V _{DV}	Velocity of dispersed vapor phase, ft/s
V _{TL}	Velocity of total liquid phase, ft/s
V _{DL}	Velocity of dispersed liquid phase, ft/s
V _{DLL}	Velocity of dispersed light liquid phase, ft/s
V _{DHL}	Velocity of dispersed heavy liquid phase, ft/s
V _{HL}	Velocity of continuous heavy liquid phase, ft/s
X	Distance top of vessel to maximum liquid level as a fraction of D
Y	$\frac{L}{D} - 1$
Z	Fraction of cross-section area corresponding to X
T	Time, minutes
ρ_L	Liquid density, lb/ft ³
ρ_V	Vapor density, lb/ft ³
Q _{CV}	Vapor flow rate, ft ³ ·s
μ_V	Vapor viscosity, lb/ft·s
D _{PL}	Liquid particle diam., ft (Use 0.00057 ft in the absence of specific process data)

EDS-R00-3424

$$T = \frac{XD}{V_{DL}} = \frac{YD}{V_{CV}}$$

$$V_{CV} = \frac{Q_{CV}}{Z(0.785 D^2)}$$

$$XD V_{CV} = YD V_{DL} \quad V_{DL} = \frac{0.153 g^{0.71} D_{PL}^{1.14} (\rho_L - \rho_V)^{0.71}}{\rho_V^{0.29} \mu_V^{0.43}} \quad (\text{Intermediate Law})$$

$$\frac{XD Q_{CV}}{Z(0.785 D^2)} = \frac{YD 0.153 g^{0.71} D_{PL}^{1.14} (\rho_L - \rho_V)^{0.71}}{\rho_V^{0.29} \mu_V^{0.43}}$$

$$D = \left[\frac{X}{0.785(0.153)YZ} \right]^{0.5} \left[\frac{Q_{CV} \rho_V^{0.29} \mu_V^{0.43}}{g^{0.71} D_{PL}^{1.14} (\rho_L - \rho_V)^{0.71}} \right]^{0.5}$$

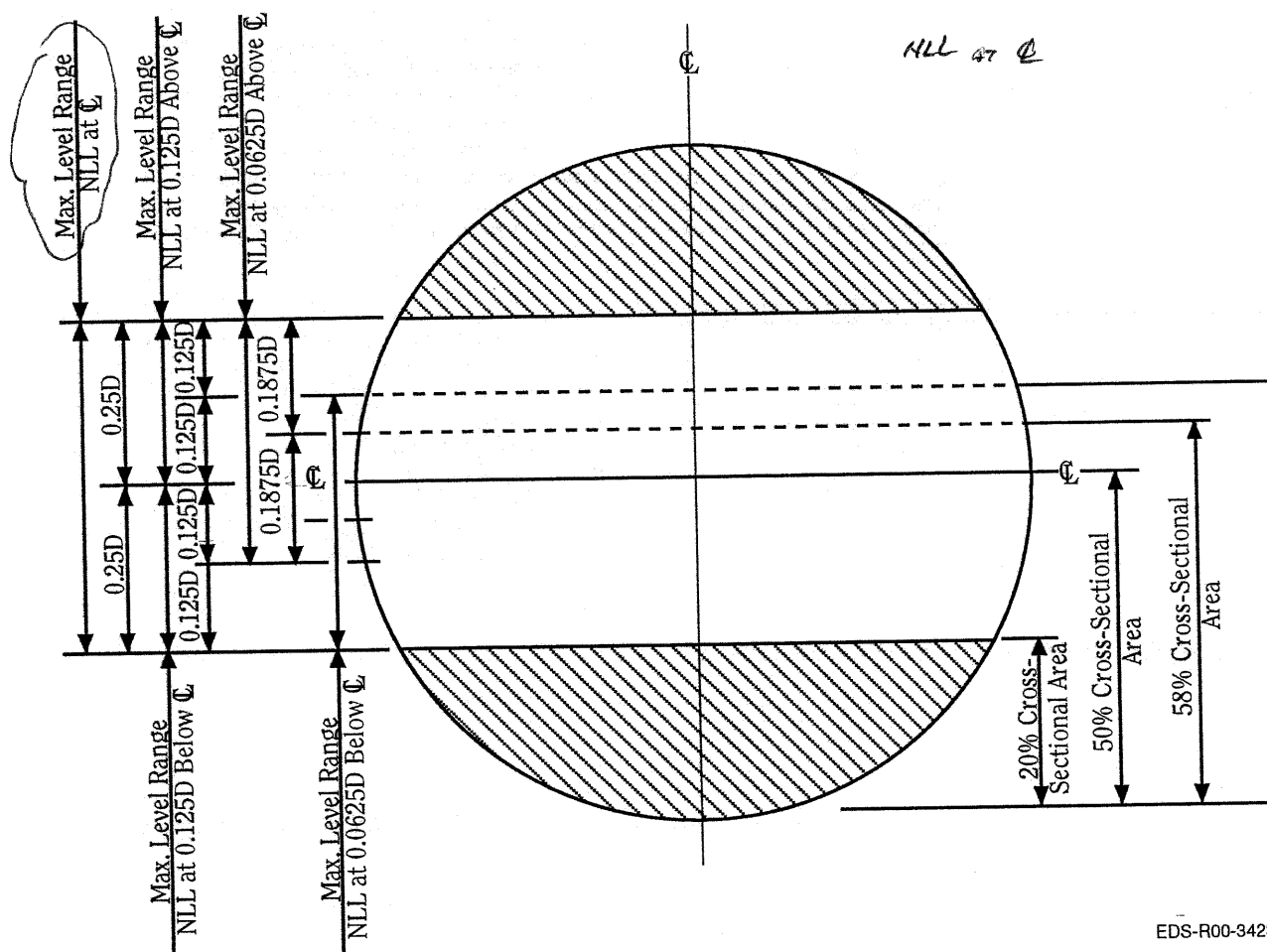
$$D = C \left[\frac{Q_{CV} \rho_V^{0.29} \mu_V^{0.43}}{g^{0.71} D_{PL}^{1.14} (\rho_L - \rho_V)^{0.71}} \right]^{0.5}$$

(Equation 2)

APPENDIX 3

Horizontal Vessel Level Relationships

Normal Level/Cross-Sectional Area/Residence Time Relationship



EDS-R00-3423

Normal Liquid Level Elevations	Percent of Vessel Liquid Full	Allowable Level Range	Time from Low Level to High Level of Allowable Level Range Based on Following Vessel Design Residence Times, Minutes						
			5	10	15	20	25	30	35
0.125D Below CL	34	0.25D	4.4	8.8	13.2	17.6	22.1	26.5	30.9
0.0625D Below CL	42	0.375D	5.5	10.9	16.4	21.9	27.4	32.9	38.3
At CL	50	0.5D	6.0	12.0	18.0	24.0	30.0	36.0	42.0
0.0625D Above CL	58	0.375D	4.0	7.9	11.9	15.9	19.8	23.8	27.8
0.125D Above CL	66	0.25D	2.3	4.5	6.8	9.1	11.4	13.6	15.9

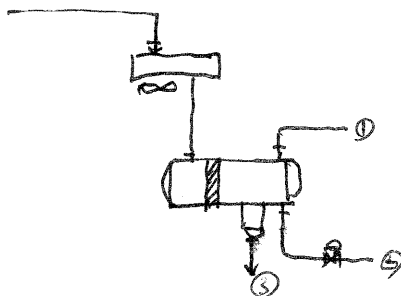
Horizontal Vessel Sizing Example

Design a Reactor Products Separator for a Naphtha Hydrotreating Process Unit. The relevant portion of the heat and material balance is reproduced below. Then complete the attached Project Specification 301 form for the vessel.

BY:

Note:

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[illegible]

APPENDIX 4 Continued

Horizontal Vessel Sizing Example

Tabulate data and calculate volumetric flows:

	Vapor	Hydrocarbon Liquid	Water Liquid
Flow, lb/h	693	58586	2250
, ft ³ /s	1.54	0.35	0.01
, gal/min	—	158	5
Density, lb/ft ³	0.125	46.34	61.55
Viscosity, cP	0.01	0.42	0.51
, lb/ft sec ($\times 10^{-4}$)	0.06	2.82	3.42

Calculate the diameter based on residence time.

Select $L/D = 3$

For settling water phase from light hydrocarbon phase, use 10 minute residence time.

Set normal liquid level (NLL) at centerline.

Calculate liquid volume:

$$V_L = Q_L t = \left(\frac{0.36 \text{ ft}^3}{s} \right) \left(\frac{60 s}{min} \right) (10 \text{ min}) = 216 \text{ ft}^3$$

If vessel is 1/2 full, then full vessel volume is:

$$V_V = \frac{V_L}{F} = \frac{216 \text{ ft}^3}{0.50} = 432 \text{ ft}^3$$

APPENDIX 4 Continued

V_V is a cylinder with $L/D = 3$

$$V_V = \frac{\pi D^2 L}{4} = \frac{3\pi D^3}{4}$$

$$D = \left[\frac{4V_V}{3\pi} \right]^{1/3} = \left[\frac{4(432 \text{ ft}^3)}{3\pi} \right]^{1/3}$$

$$D = 5.7 \text{ feet}$$

(IGNORE HEAD VOLUME)

Calculate the diameter based on liquid from vapor separation.

For NLL at centerline, maximum level is $0.25D$ from top of vessel ($X = 0.25$ and $Z = 0.20$), and $L/D = 3$ (thus $Y = 2$), use the equation from page 12.

$$D = 2.28 \left[\frac{Q_{CV} \rho_V^{0.29} \mu_V^{0.43}}{g^{0.71} D_{PL}^{1.14} (\rho_L - \rho_V)^{0.71}} \right]^{0.5}$$

$$Q_{CV} = 1.54 \text{ ft}^3/\text{s}$$

$$\rho_V = 0.125 \text{ lb/ft}^3$$

$$\rho_L = 46.34 \text{ lb/ft}^3$$

$$\mu_V = 0.06 \times 10^{-4} \text{ lb/ft} \cdot \text{sec}$$

$$g = 32.2 \text{ ft/s}^2$$

$$D = 2.28 \left[\frac{(1.54)(0.125)^{0.29} (0.000006)^{0.43}}{(32.2)^{0.71} (0.00082)^{1.14} (46.34 - 0.125)^{0.71}} \right]^{0.5}$$

$$D = 0.68 \text{ feet}$$

APPENDIX 4 Continued

Calculate the diameter based on vapor from liquid separation.

The terminal velocity of the bubble rising in the liquid, V_{DV} , is calculated with Stokes' Law.

$$V_{DV} = \frac{g D_{PV}^2 (\rho_L - \rho_V)}{18 \mu_L}$$

↑ CONTINUOUS
↓ DISPERSED

If X is the distance from the bottom of the vessel to the minimum level, expressed as a fraction of the diameter D , then the time, T for the bubble to rise a distance XD is:

$$T = \frac{XD}{V_{DV}}$$

The horizontal velocity of the liquid phase is the volumetric flow of liquid divided by the flow area.

$$V_L = \frac{Q_L}{Z(0.785D^2)(7.48)(60)} = \frac{Q_L}{352.3 Z D^2}$$

where:

Q_L is the liquid flow rate, gpm

Z is the fraction of cross-sectional area corresponding to X

$0.785D^2$ is the total cross-sectional area

$(7.48)(60)$ converts from ft^3/s to gpm

APPENDIX 4 Continued

If $Y = L/D - 1$, then the time for the liquid to flow from the inlet to the outlet is:

$$T = \frac{YD}{V_L}$$

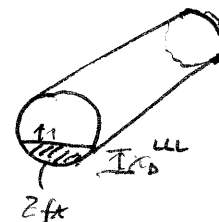
In the worst case, the time for the bubble to rise XD is equal to the time for the liquid to flow YD , and:

$$T = \frac{XD}{V_{DV}} = \frac{YD}{V_L}$$

$$XD V_L = YD V_{DV}$$

Substitute:

$$\frac{XD Q_L}{352.3 Z D^2} = \frac{Y D g D_{PV}^2 (\rho_L - \rho_V)}{18 \mu_L}$$



Solve for D :

$$D = \left[\frac{18 X}{352.3 Z Y} \right]^{0.5} \left[\frac{Q_L \mu_L}{g D_{PV}^2 (\rho_L - \rho_V)} \right]^{0.5}$$

For $X = 0.25$, then $Z = 0.20$

For $L/D = 3$, then $Y = 2$

And:

$$D = 0.18 \left[\frac{Q_L \mu_L}{g D_{PV}^2 (\rho_L - \rho_V)} \right]^{0.5}$$

APPENDIX 4 Continued

$$D = 0.18 \left[\frac{(163)(0.000282)}{(32.2)(0.00057)^2 (46.34 - 0.125)} \right]^{0.5}$$

$$D = 1.75 \text{ feet}$$

This does not govern

Calculate the diameter based on liquid/liquid separation.

The method uses Stokes' Law to calculate the terminal velocity of the heavy liquid droplet and is very similar to the vapor from liquid case.

Use subscripts *HL* and *LL* for heavy liquid and light liquid.

From Stokes Equation:

$$V_{HL} = \frac{g D_{PH}^2 (\rho_{HL} - \rho_{LL})}{18 \mu_{LL}}$$

and:

$$T = \frac{XD}{V_{HL}} = \frac{YD}{V_L}$$

Substitute and solve for *D*:

$$D = \left[\frac{18X}{352.3YZ} \right]^{0.5} \left[\frac{Q_L \mu_{LL}}{g D_{PH}^2 (\rho_{HL} - \rho_{LL})} \right]^{0.5}$$

For $X = 0.25$, then $Z = 0.20$

APPENDIX 4 Continued

For $L/D = 3$, $Y = 2$

$$D = 0.18 \left[\frac{Q_L \mu_{LL}}{g D_{PH}^2 (\rho_{HL} - \rho_{LL})} \right]^{0.5}$$

$$D = 0.18 \left[\frac{(163)(0.000282)}{(32.2)(0.00041)^2 (61.55 - 46.34)} \right]^{0.5}$$

$$D = 4.2 \text{ feet}$$

The governing diameter, 5.7 feet, was that determined in Case I, based on the liquid residence time. Round to:

$$D = 6 \text{ feet}$$

$$L = 3D = 18 \text{ feet}$$

Vessel Drop Leg (Boot)

Size the drop leg for 10 minute residence time for the water phase.

Size drop leg for separation of dispersed hydrocarbon liquid phase from a continuous water phase.

Use Stokes' Law to determine the terminal velocity of the dispersed liquid droplet.

$$V_{DLL} = \frac{g D_{PL}^2 (\rho_{HL} - \rho_{LL})}{18 \mu_{HL}}$$

The velocity of the continuous heavy phase (water) is the volumetric flow rate divided by the cross-sectional area of the drop leg.

APPENDIX 4 Continued

$$V_{CHL} = \frac{Q_{CHL}}{A_{DL}} = \frac{Q_{CHL}}{0.785 D_{DL}^2}$$

Now set the velocity of the continuous water phase, V_{CHL} , equal to the terminal velocity of the hydrocarbon droplet, V_{DLL} , and solve for the diameter of the drop leg, D_{DL} .

$$V_{CHL} = V_{DLL} = \frac{Q_{CHL}}{0.785 D_{DL}^2 (7.48)(60)} = \frac{g D_{PL}^2 (\rho_{HL} - \rho_{LL})}{18 \mu_{HL}}$$

$$D_{DL} = 2.71 \left[\frac{Q_{CHL} \mu_{HL}}{g D_{PL}^2 (\rho_{HL} - \rho_{LL})} \right]^{0.5}$$

$$D_{DL} = 2.71 \left[\frac{(5)(0.000342)}{(32.2)(0.00041)^2 (61.55 - 46.34)} \right]^{0.5}$$

$$D_{DL} = 12.4 \text{ inches}$$

Calculate the drop leg diameter based upon the 10 minute residence time and a drop leg length of 3.5 feet.

$$V_{DL} = Q_{CHL} t = \frac{\pi D_{DL}^2 L}{4}$$

$$\left(\frac{5 \text{ gal}}{\text{min}} \right) (10 \text{ min}) \left(\frac{\text{ft}^3}{7.48 \text{ gal}} \right) = \frac{3.5 \pi D_{DL}^2}{4}$$

$$D_{DL}^2 = 2.43$$

$$D_{DL} = 1.56 \text{ ft} = 18.7 \text{ in}$$

APPENDIX 4 Continued

Select the largest calculated drop leg diameter, 18.7 inches, and round to the next larger standard pipe size, 20 inch outside diameter.

Length of the drop leg is 3 feet–6 inches.

Since the drop leg is less than 30 inches outside diameter and the vessel is internally lined, the drop leg will be flanged to the vessel.



APPENDIX 4, Concluded

25 East Algonquin Road • Des Plaines, Illinois 60017-5017 • USA

PROJECT SPECIFICATION 6163 - 301 - SHEET

REV	DATE	BY	APP'D	REV	DATE	BY	APP'D

VESSELS

SERVICE REACTOR PRODUCTS SEPARATOR

ITEM NO

F-2022

Design INT 280 psig. e250 °F (#) BY CONTRACTOR

Conditions EXT FULL VACUUM e130 °F

at Top Metal Temperature (Min) °F

Operating 130 °F

Conditions °F

Radiograph MR

Postweld Heat Treat YES

Joint Efficiency MR %

Material Specifications

Heads KILLED CARBON STEEL

Shell KILLED CARBON STEEL

Drop Leg KILLED CARBON STEEL

D.L. Head KILLED CARBON STEEL

Shell Thickness Required by Code-in. Corrosion Allowance in. (Min)

VESEL 0.125/0.1875 LINED

DROP LEG 0.125 LINED

Heads

VESEL 0.125/0.1875 LINED

DROP LEG 0.125 LINED

Vessel Heads

Vessel 2:1 ELLIPTICAL

Drop Leg 2:1 ELLIPTICAL

Accessories Applied by Fabricator

Ladder & Platform Clips AS REQUIRED (#)

Insulation Clips & Rings NO

Vessel Support YES

Nozzles and Manways

Mark No Size Inches Service

AI 1 8 INLET

AM 1 18 ID MANWAY

AU 1 3 ID RELIEF

BB 1 6 VENTILATION

BK 2 2 LC-LG

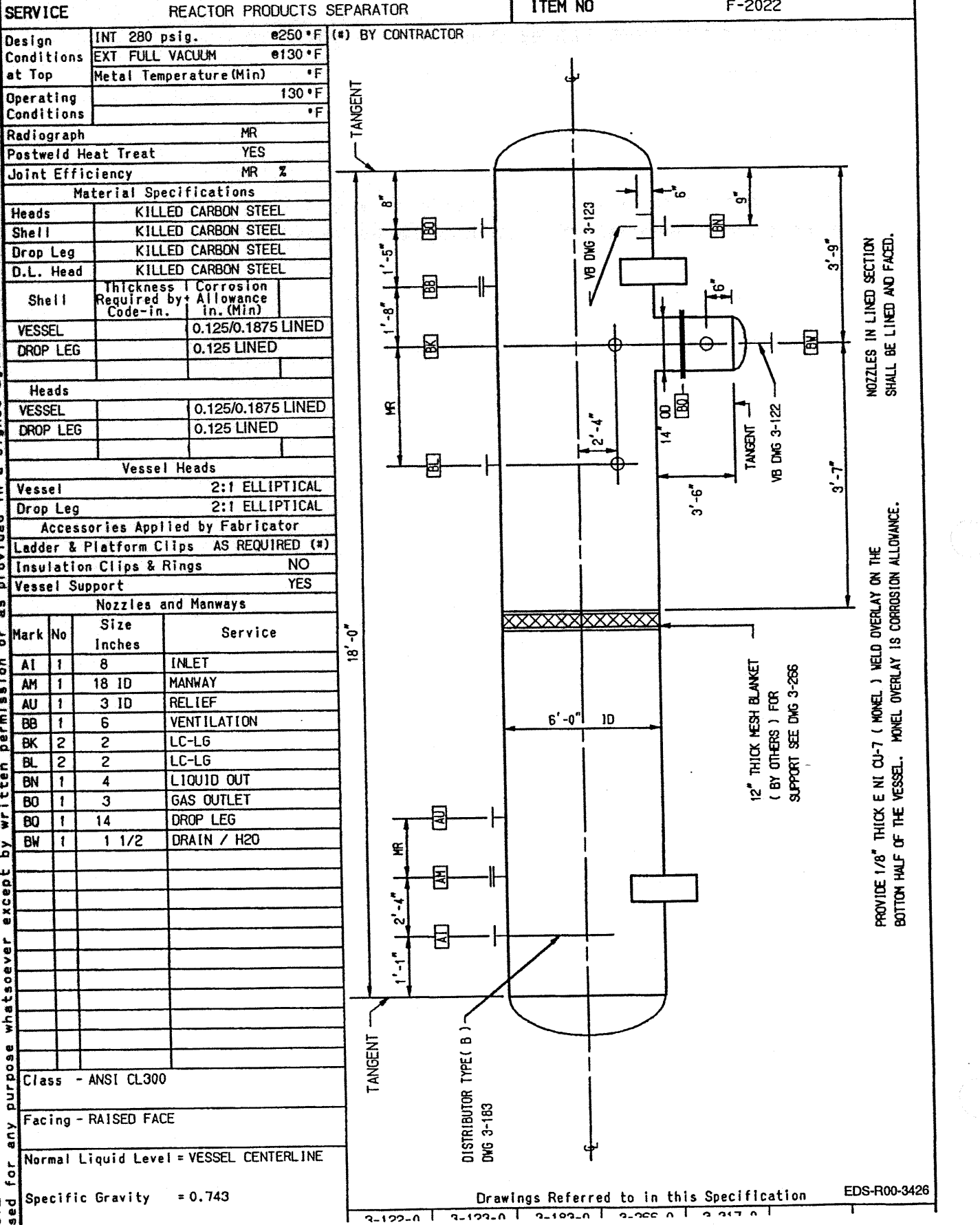
BL 2 2 LC-LG

BN 1 4 LIQUID OUT

BO 1 3 GAS OUTLET

BO 1 14 DROP LEG

BW 1 1 1/2 DRAIN / H2O

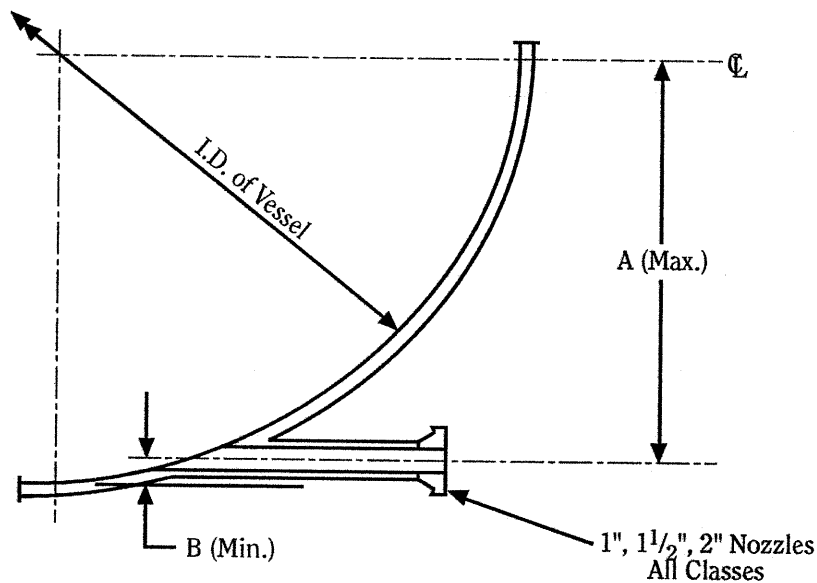


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APPENDIX 5

Tangential Nozzle Limitations

*Design Limitations for
Tangential Nozzles on Horizontal Vessels*



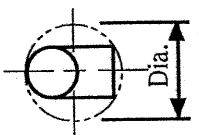
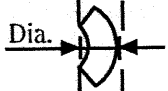
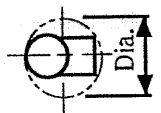
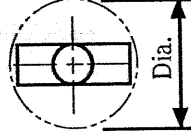
EDS-R00-3427

Inside Diameter of Vessel	A Maximum	B Minimum	Inside Diameter of Vessel	A Maximum	B Minimum
3'-0"	1'-4 1/2"	1 1/2"	7'-0"	3'-3"	3"
3'-6"	1'-7"	2"	7'-6"	3'-5 1/2"	3 1/2"
4'-0"	1'-10"	2"	8'-0"	3'-8 1/2"	3 1/2"
4'-6"	2'-1"	2"	8'-6"	3'-11"	4"
5'-0"	2'-3 1/2"	2 1/2"	9'-0"	4'-2"	4"
5'-6"	2'-6 1/2"	2 1/2"	10'-0"	4'-7 1/2"	4 1/2"
6'-0"	2'-9 1/2"	2 1/2"	11'-0"	5'-1"	5"
6'-6"	3'-0"	3"	12'-0"	5'-6 1/2"	5 1/2"

To simplify fabrication, a minimum "B" dimension of 6 inches is recommended when processing conditions will permit.

APPENDIX 6

Minimum Openings Required for Pipe Fittings

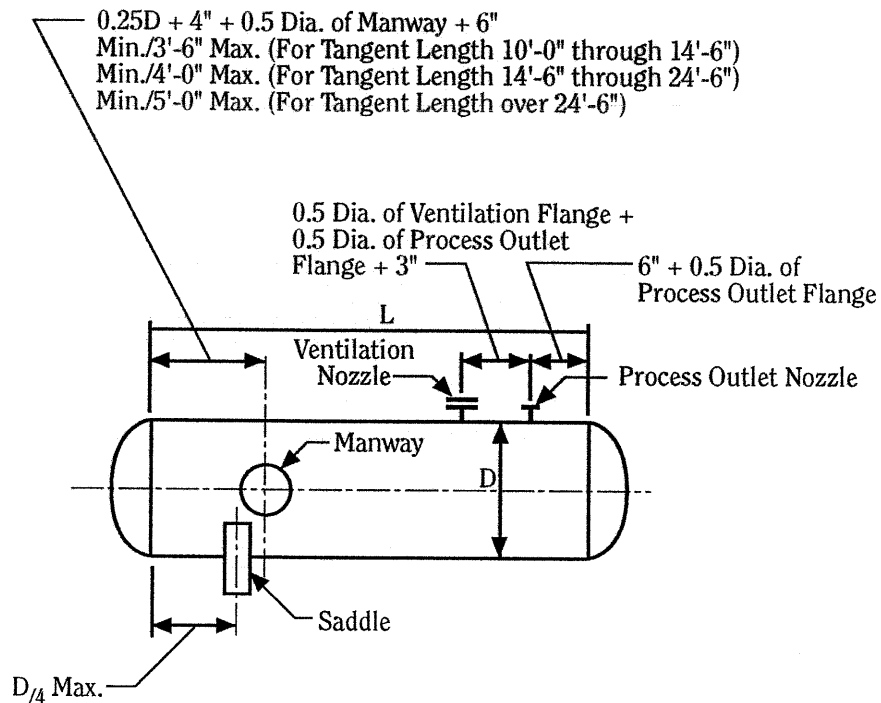
Nom. Pipe Size				
	90° L.R. ELL (S.R. ELL)	90° L.R. ELL (S.R. ELL)	Straight Tee	Straight Cross
6"	13.25"	8.5"	10.25"	13.25"
8"	17.5"	11.0"	13.0"	16.5"
10"	22.0"	13.75"	16.0"	20.25"
12"	26.25" (20.75")	16.25" (14.5")	19.0"	23.75"
14"	30.0" (23.5")	18.25" (16.25")	21.0"	26.25"
16"	34.0" (26.75")	20.75" (18.5")	23.25"	29.0"
18"	38.25" (30.0")	23.5" (20.75")	26.25"	32.5"
20"	42.5" (33.5")	26.0" (23.0")	29.0"	36.25"
22"	46.75" (36.75")	28.5" (25.25")	32.0"	40.0"
24"	51.0" (40.0")	31.25" (27.5")	34.0"	41.75"

Note: Diameter is rounded off to the next quarter inch
22" pipe size is not recommended.

EDS-R00-3428

APPENDIX 7

Manway/Ventilation Nozzle Location



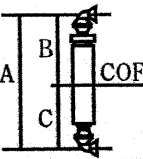
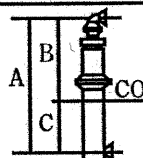
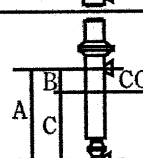
- Basis:
1. 24" Manway with a 6" Reinforcing Pad.
 2. Assuming that the L/D Ratio of the Vessel is 3 to 1.
 3. Inlet is at the Top or on the Side.
 These Dimensions should be Checked when Process Inlet is from Bottom.
 4. Saddle Width of 8".

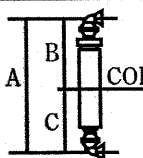
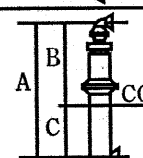
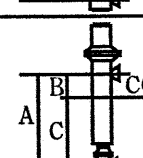
EDS-R00-3429

APPENDIX 8

Standard Level Instrument Sizes

Minimum Spacing (English/Metric) for External Displacement Type Instrument Connections

Float Length		14"	32"	48"	60"	72"	84"	96"	120"
	A	4'-0"	5'-6"	6'-10"	7'-10"	8'-10"	9'-10"	10'-10"	12'-10"
	B	2'-2"	2'-11"	3'-7"	4'-1"	4'-7"	5'-1"	5'-7"	6'-7"
	C	1'-10"	2'-7"	3'-3"	3'-9"	4'-3"	4'-9"	5'-3"	6'-3"
	A	2'-9"	4'-3"	5'-7"	6'-7"	7'-7"	8'-7"	9'-7"	11'-7"
	B	2'-2"	2'-11"	3'-7"	4'-1"	4'-7"	5'-1"	5'-7"	6'-7"
	C	7"	1'-4"	2'-0"	2'-6"	3'-0"	3'-6"	4'-0"	5'-0"
	A	2'-5"	3'-11"	5'-3"	6'-3"	7'-3"	8'-3"	9'-3"	11'-3"
	B	7"	1'-4"	2'-0"	2'-6"	3'-0"	3'-6"	4'-0"	5'-0"
	C	1'-10"	2'-7"	3'-3"	3'-9"	4'-3"	4'-9"	5'-3"	6'-3"

Float Length		356	813	1219	1524	1829	2134	2438	3048
	A	1220	1675	2085	2390	2695	3000	3300	3910
	B	660	890	1095	1245	1400	1550	1700	2005
	C	560	785	990	1145	1295	1450	1600	1905
	A	840	1295	1705	2005	2315	2615	2920	3530
	B	660	890	1095	1245	1400	1550	1700	2005
	C	180	405	610	760	915	1065	1220	1525
	A	740	1190	1600	1905	2210	2515	2820	3430
	B	180	405	610	760	915	1065	1220	1525
	C	560	785	990	1145	1295	1450	1600	1905

Notes:

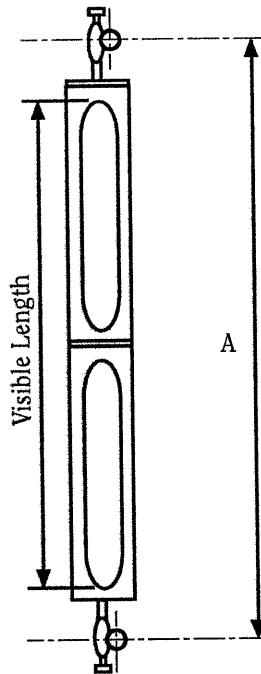
1. Dimensions given for flanged connections are suitable for ANSI Class 150, 300 and 600 raised face and ring type joints.

EDS-R00-3430

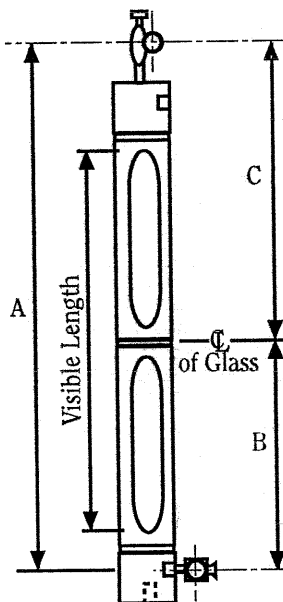
APPENDIX 8 Continued

Standard Level Instrument Sizes

*Minimum Spacing (English/Metric) of Level Gauge Connections
Approximate Dimensions for Jerguson Series 10 and 20 Level Gauges
Normal Length to be Indicated on P&I Diagram*



End Connections					
Normal Length		Standard Visible Length		Dimension A	
1'-0"	300	12 ⁵ / ₈ "	320	1'-9"	535
1'-6"	450	19 ³ / ₄ "	501	2'-4"	710
2'-0"	600	25 ¹ / ₄ "	641	2'-9"	840
2'-6"	750	30 ³ / ₈ "	771	3'-2"	965
3'-0"	900	38 ⁵ / ₈ "	981	3'-11"	1195
3'-6"	1050	45 ¹ / ₂ "	1155	4'-5"	1346
4'-0"	1200	52"	1320	5'-0"	1525
4'-6"	1350	55"	1397	5'-3"	1600
5'-0"	1500	65 ³ / ₈ "	1660	6'-1"	1855
5'-6"	1650	69 ¹ / ₈ "	1755	6'-5"	1955



Close Hook-Up Connections									
Normal Length		Standard Visible Length		Dimension A		Dimension B		Dimension C	
1'-0"	300	12 ⁵ / ₈ "	320	1'-6"	460	7"	180	11"	280
1'-6"	450	19 ³ / ₄ "	501	2'-2"	660	11"	280	1'-3"	380
2'-0"	600	25 ¹ / ₄ "	641	2'-7"	785	1'-2"	355	1'-5"	430
2'-6"	750	30 ³ / ₈ "	771	3'-0"	915	1'-4"	405	1'-8"	510
3'-0"	900	38 ⁵ / ₈ "	981	3'-8"	1120	1'-8"	510	2'-0"	610
3'-6"	1050	45 ¹ / ₂ "	1155	4'-3"	1295	2'-0"	610	2'-3"	685
4'-0"	1200	52"	1320	4'-10"	1475	2'-3"	685	2'-7"	790
4'-6"	1350	55"	1397	5'-1"	1555	2'-5"	740	2'-8"	815
5'-0"	1500	65 ³ / ₈ "	1660	5'-10"	1780	2'-9"	840	3'-1"	940
5'-6"	1650	69 ¹ / ₈ "	1755	6'-3"	1905	3'-0"	915	3'-3"	990

EDS-R00-3431



APPENDIX 9 Continued

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HORIZONTAL PIPE DISTRIBUTOR FOR HORIZONTAL VESSELS

DWG. NO.

REV.

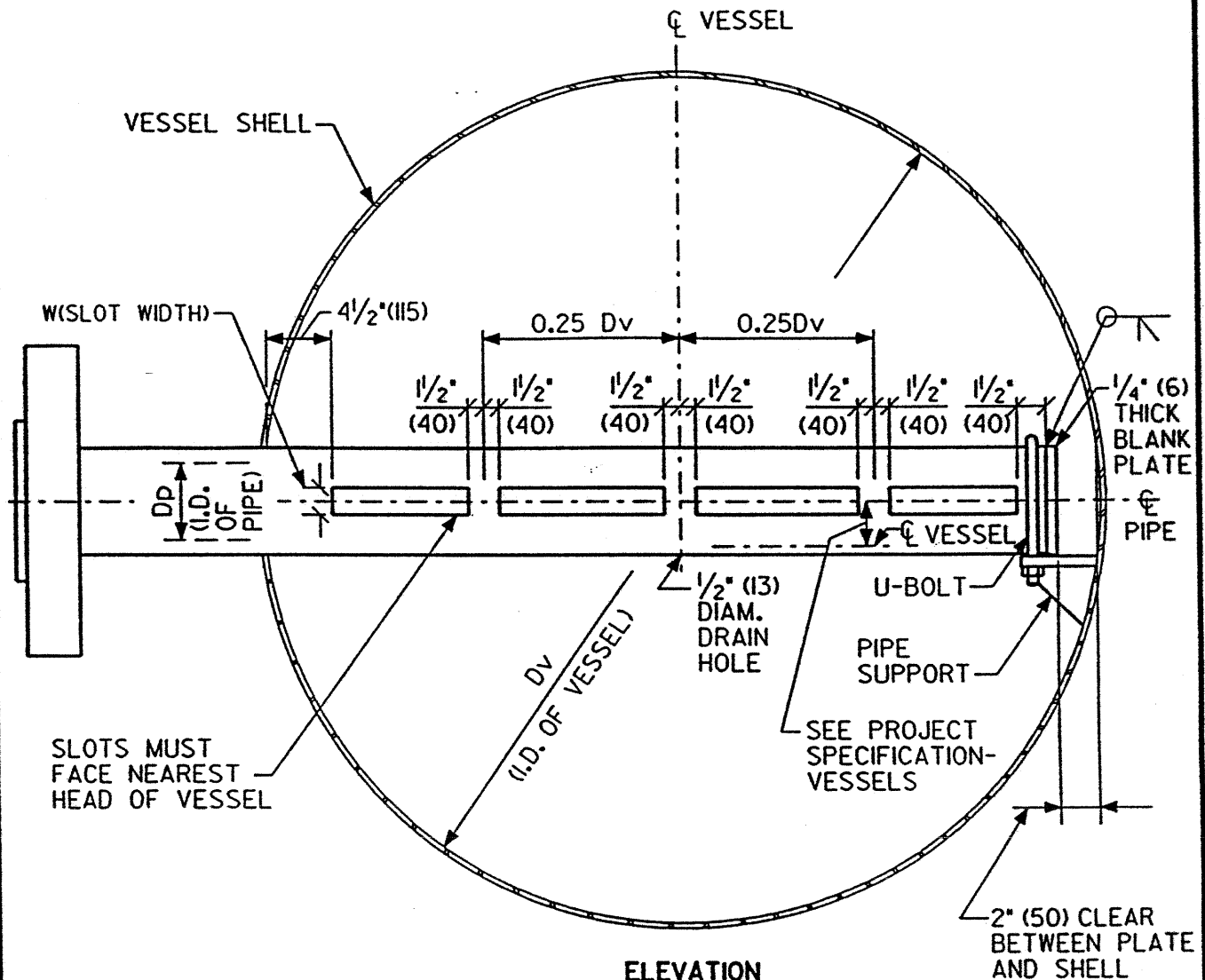
C17058-A

1

DR. BGA CK. RJB

APPR. RJB DATE 15JUN90

PROJECT 8005



$$W = \frac{2D_p^2}{D_v - 17} \quad (\text{ALL DIMENSIONS ARE IN INCHES})$$

$$W = \frac{2D_p^2}{D_v - 430} \quad (\text{ALL DIMENSIONS ARE IN MILLIMETERS})$$

NOTES:

1. DETAILS AND DIMENSIONS SHOWN IN PROJECT SPECIFICATION - VESSELS TAKE PRECEDENCE OVER THOSE SHOWN HEREON.
2. SEE UOP DWG. 3-317 FOR DETAILS OF NOZZLE AND PIPE.
3. DIMENSIONS IN PARENTHESIS ARE IN MILLIMETERS.
4. IF W(SLOT WIDTH) CALCULATES TO BE LESS THAN 3/16" (5), WIDER AND SHORTER SLOTS SHOULD BE CONSIDERED TO PROVIDE THE SAME SLOT AREA.

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BGA/RJS/MAJ/20

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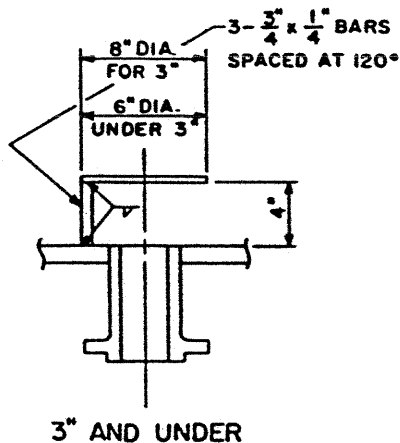
APPENDIX 9 Continued

STANDARD DRAWING

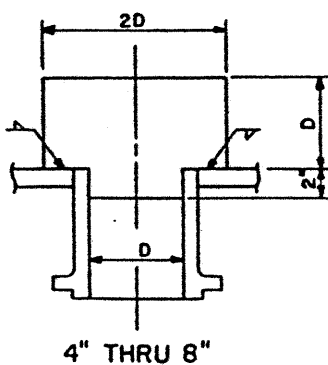
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APPROVED: *[Signature]*

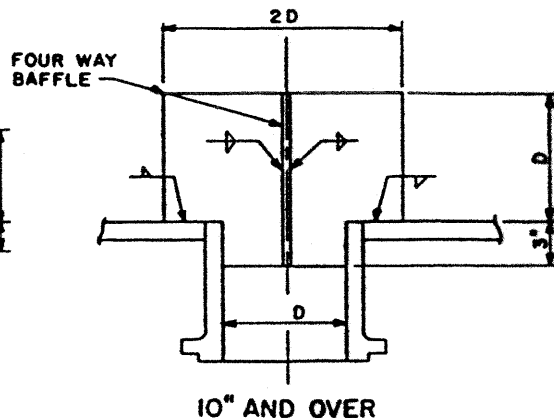
VORTEX BREAKERS



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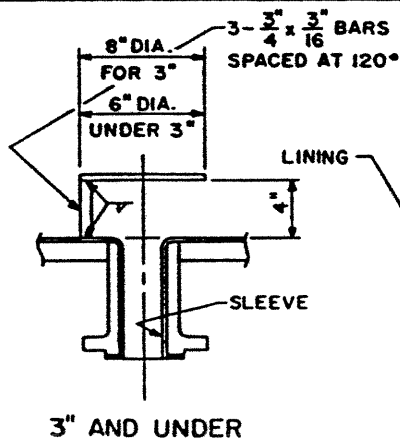


4" THRU 8"

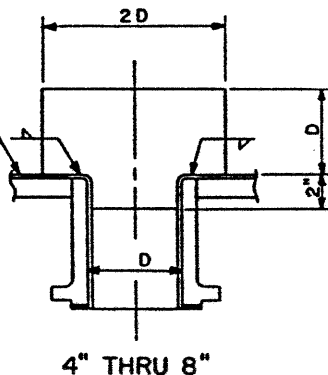


10" AND OVER

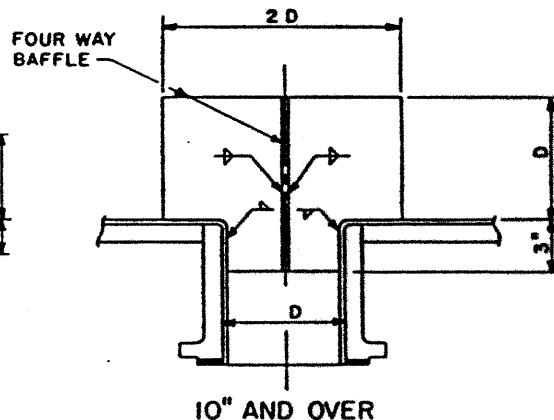
UNLINED VESSELS



3" AND UNDER

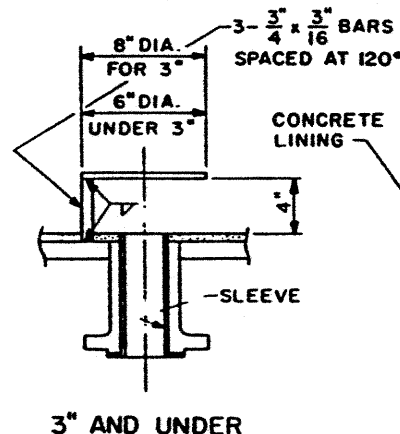


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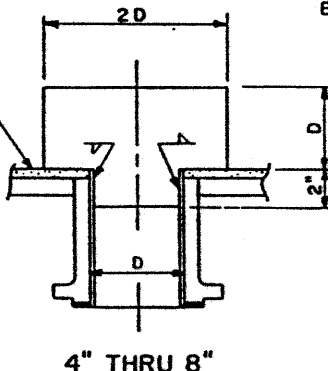


10" AND OVER

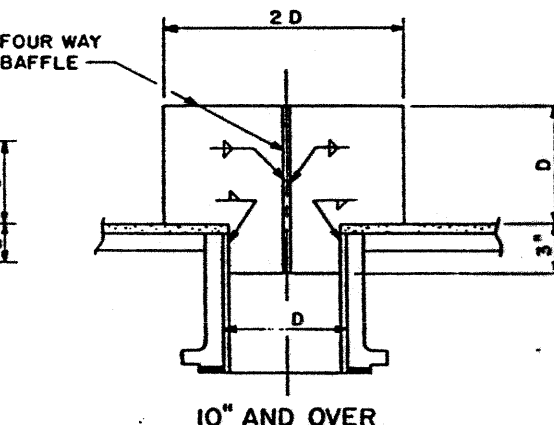
ALLOY LINED VESSELS



3" AND UNDER



4" THRU 8"



10" AND OVER

CONCRETE LINED VESSELS

NOTES:

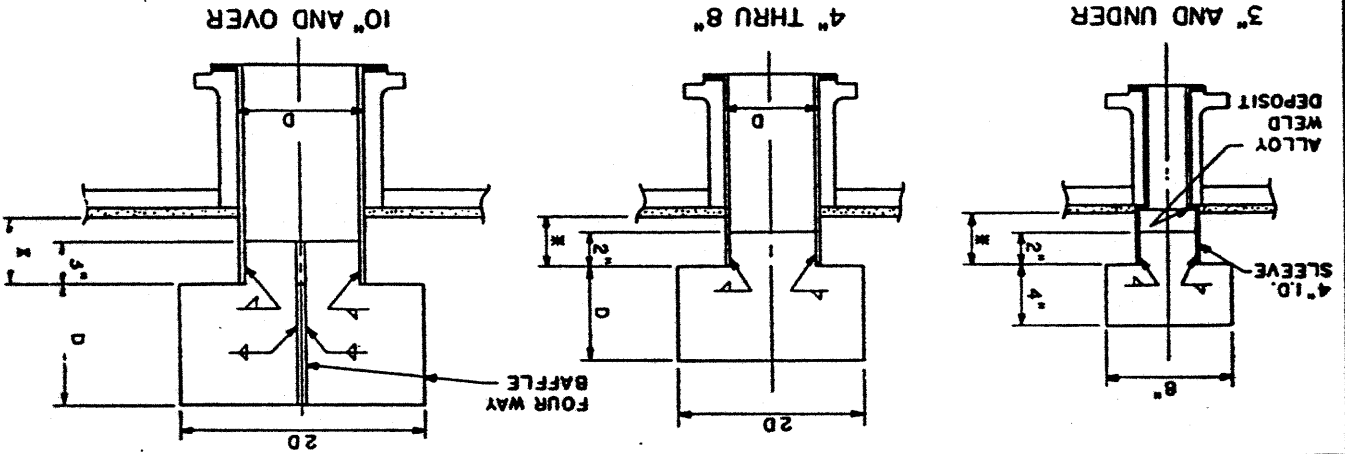
1. UNLINED VESSEL BAFFLE PLATES TO BE $\frac{1}{4}$ " CARBON STEEL.
2. ALLOY OR CONCRETE LINED BAFFLE AND SLEEVE MATERIAL SHALL BE $\frac{3}{16}$ " & SAME MATERIAL AS NOZZLE LINING.
3. DETAILS, DIMENSIONS AND NOTES IN PROJECT SPECIFICATION - VESSELS TAKE PRECEDENCE OVER THOSE SHOWN HEREON.

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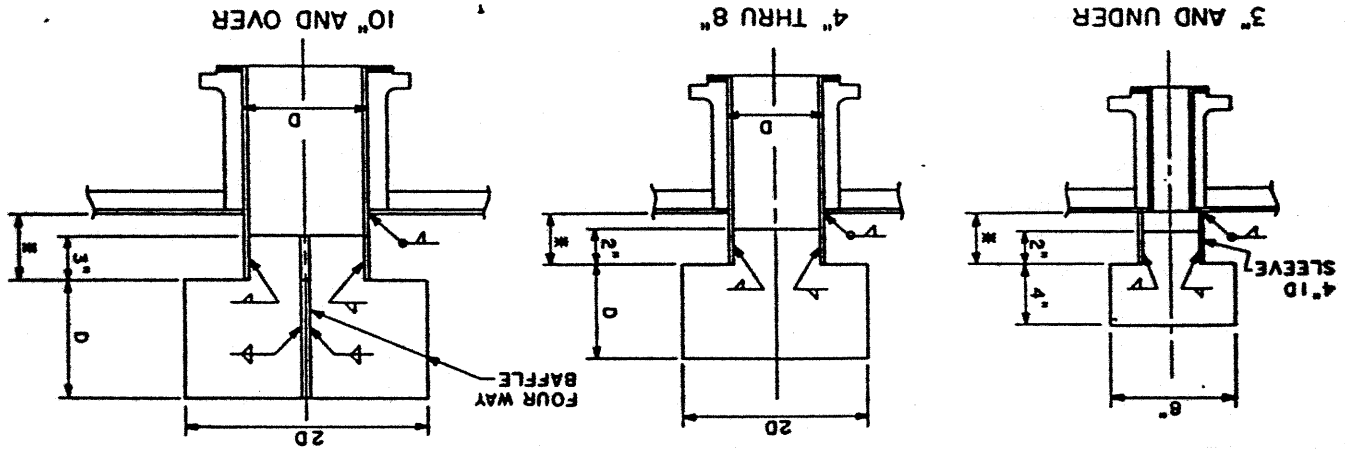
NOTES:

1. UNLINED VESSEL BAFFLE PLATES TO BE $\frac{1}{4}$ " CARBON STEEL. PIPE TO BE STANDARD WALL CARBON STEEL.
2. ALLOY OR CONCRETE LINED BAFFLE AND SLEEVE MATERIAL SHALL BE $\frac{3}{16}$ " & SAME MATERIAL AS NOZZLE LINING.
3. DETAILS, DIMENSIONS AND NOTES IN PROJECT SPECIFICATION - VESSELS TAKE PRECEDENCE OVER THOSE SHOWN HEREON.
- * SEE PROJECT SPECIFICATION - VESSELS.

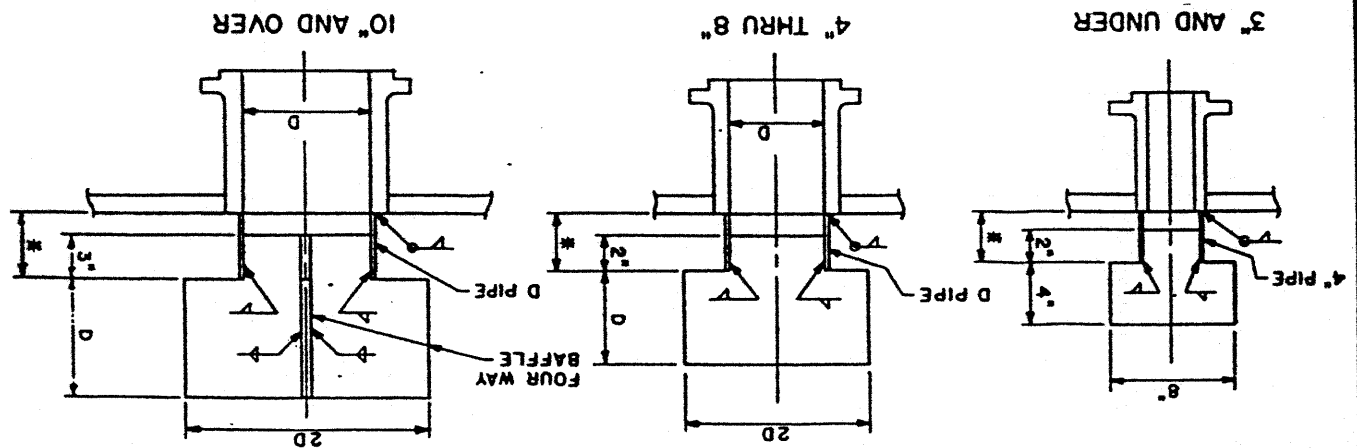
CONCRETE LINED VESSELS



ALLOY LINED VESSELS



UNLINED VESSELS



VORTEX BREAKERS

APPENDIX 9 Continued



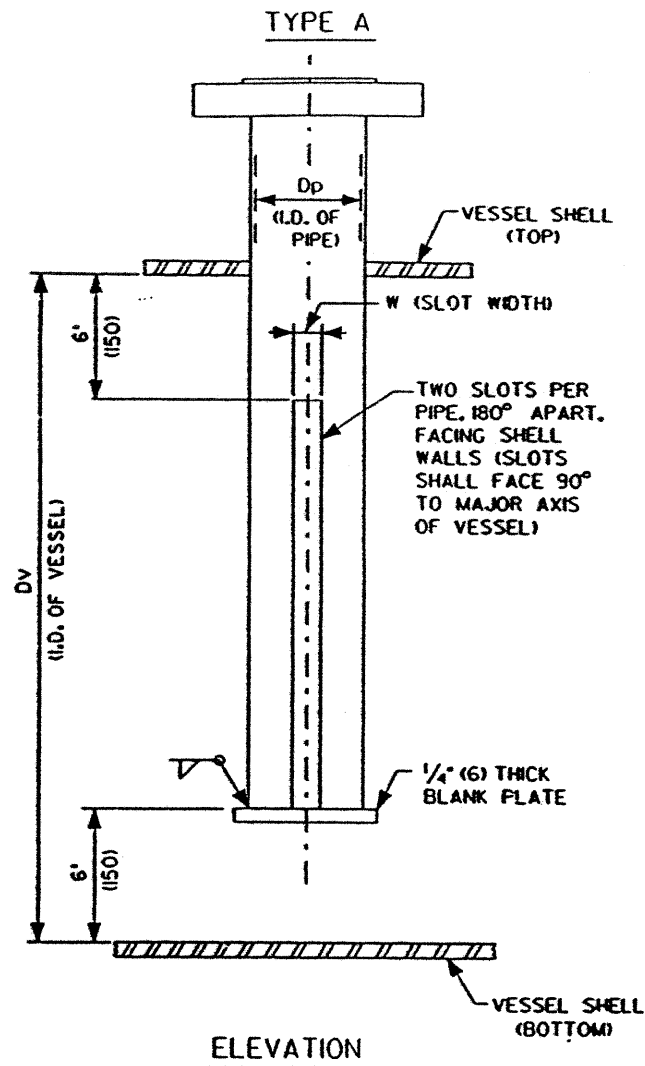
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APPROVED: *[Signature]*

3-123-0

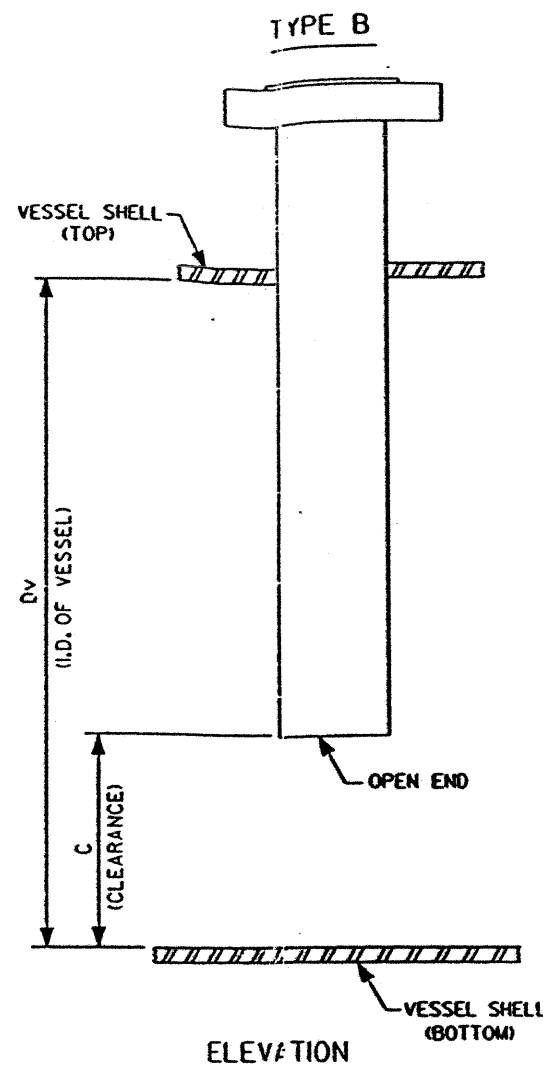
STANDARD DRAWING

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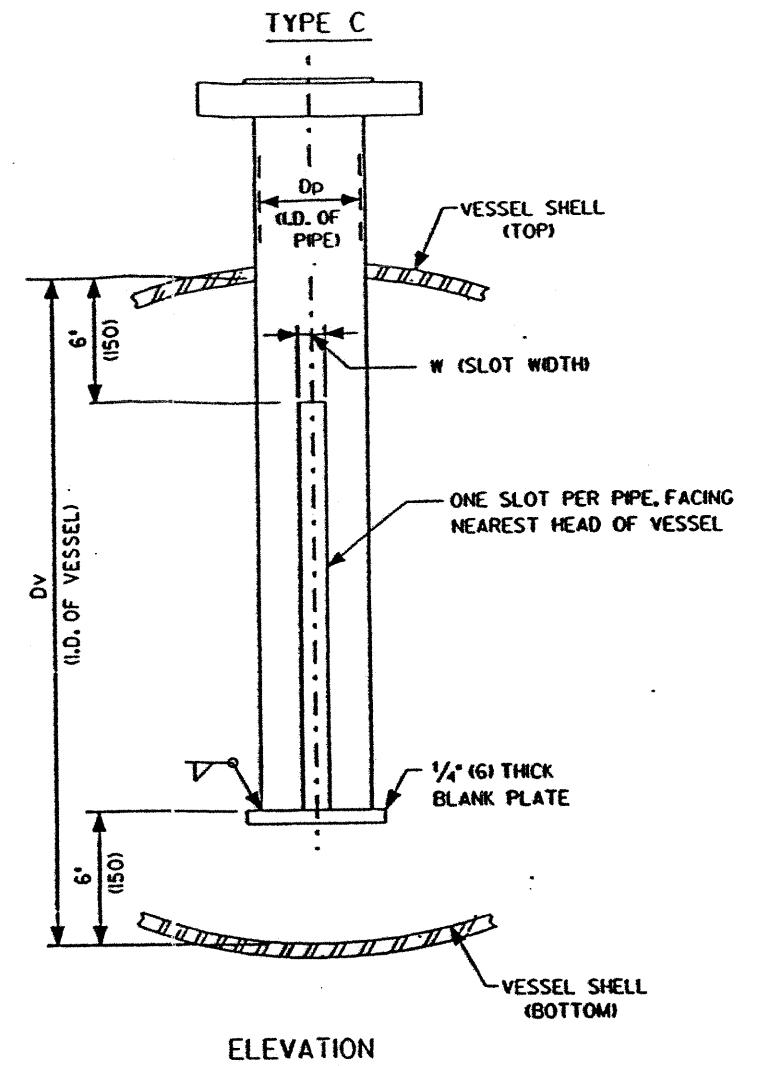
$$W = \frac{D_p^2}{D_v - 12} \quad (\text{ALL DIMENSIONS ARE IN INCHES, SLOT WIDTH TOLERANCE IS PLUS OR MINUS } \frac{1}{16} \text{")}$$

$$W = \frac{D_p^2}{D_v - 300} \quad (\text{ALL DIMENSIONS ARE IN MILLIMETERS, SLOT WIDTH TOLERANCE IS PLUS OR MINUS 2})$$



$$C = 0.25 D_v - 3 \text{"} \quad (\text{ALL DIMENSIONS ARE IN INCHES})$$

$$C = 0.25 D_v - 75 \quad (\text{ALL DIMENSIONS ARE IN MILLIMETERS})$$



$$W = \frac{2 D_p^2}{D_v - 12} \quad (\text{ALL DIMENSIONS ARE IN INCHES, SLOT WIDTH TOLERANCE IS PLUS OR MINUS } \frac{1}{16} \text{")}$$

$$W = \frac{2 D_p^2}{D_v - 300} \quad (\text{ALL DIMENSIONS ARE IN MILLIMETERS, SLOT WIDTH TOLERANCE IS PLUS OR MINUS 2})$$

NOTES:

1. DETAILS AND DIMENSIONS SHOWN IN PROJECT SPECIFICATION-VESSELS TAKE PRECEDENCE OVER THOSE SHOWN HEREON.
2. SEE UOP DWG. 3-317 FOR DETAILS OF NOZZLE AND PIPE.
3. DIMENSIONS IN PARENTHESIS ARE IN MILLIMETERS.
4. FOR TYPES A AND C IF W (SLOT WIDTH) CALCULATES TO BE LESS THAN 1/16" (51), INTERMITTENT SLOTS OF A LARGER WIDTH SHOULD BE CONSIDERED TO PROVIDE THE SAME SLOT AREA.

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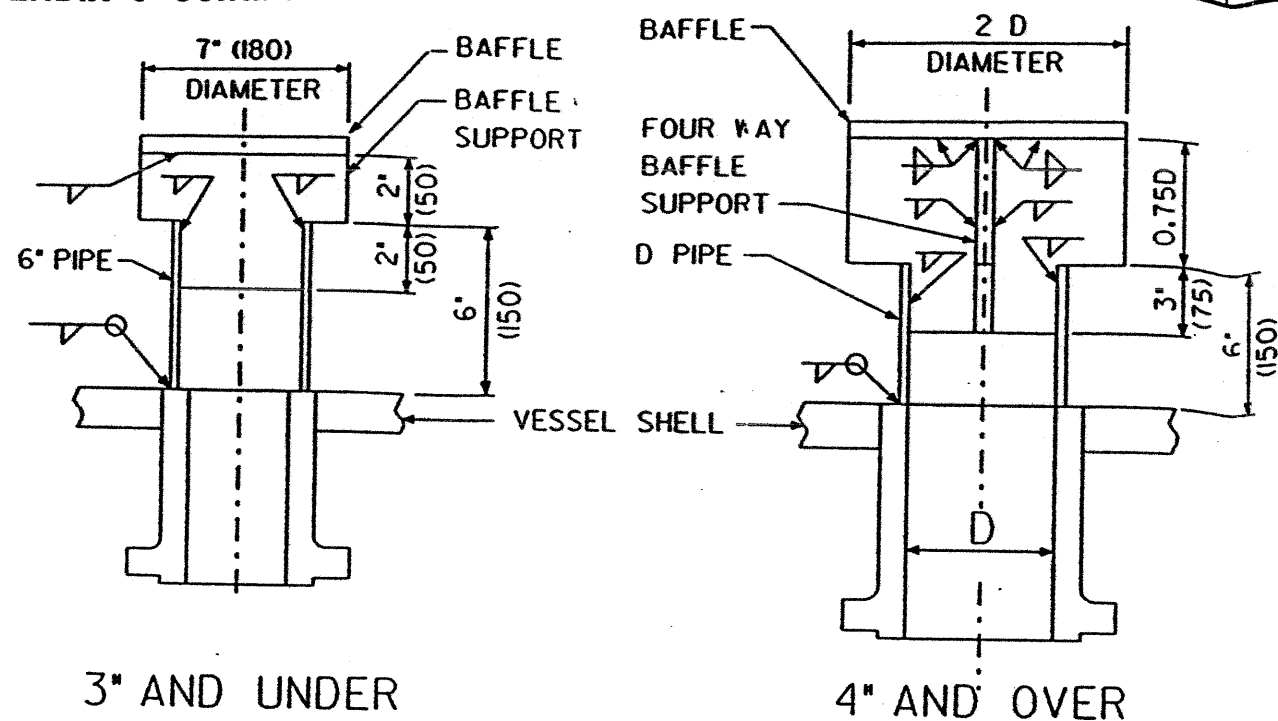
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VERTICAL PIPE DISTRIBUTORS FOR HORIZONTAL VESSELS

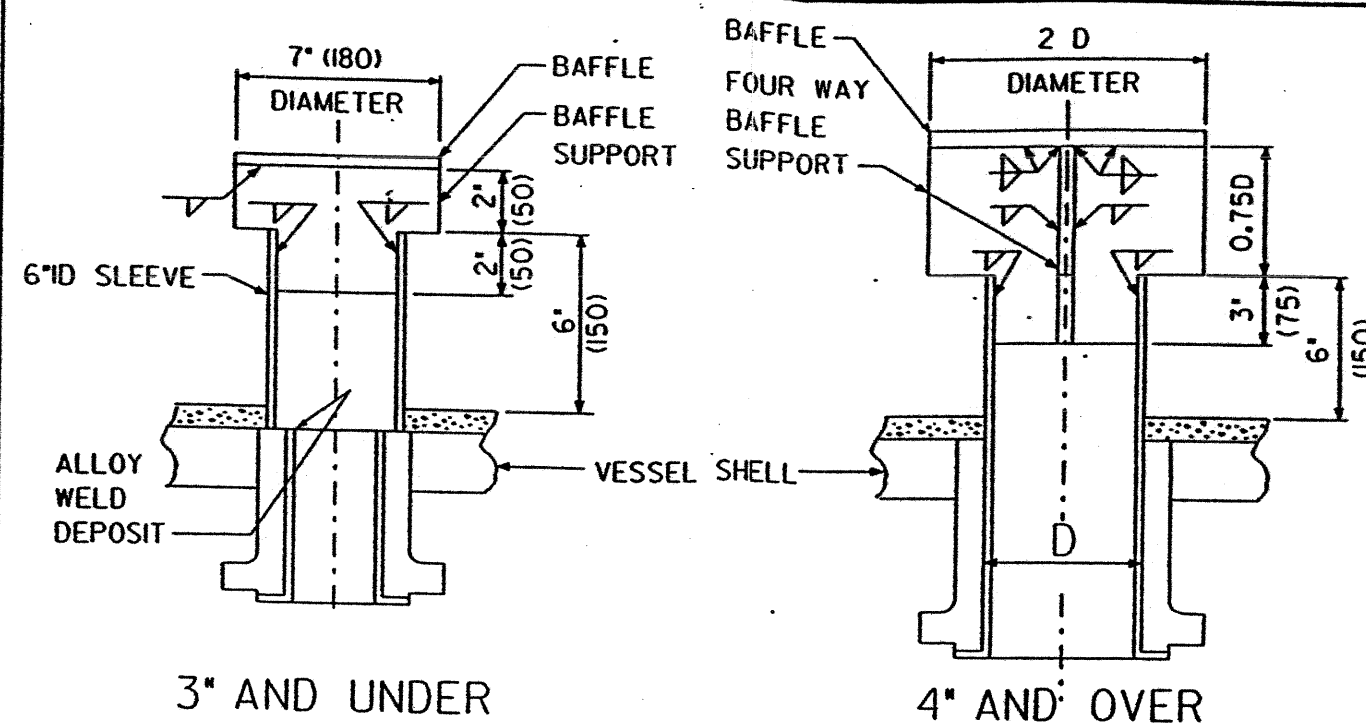
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										2	HL	RHS	RJS	21 DEC 90		BGA	RRN	BJR	6/18 90	8005	DR. BGA	CK. RRN	C17057-B	2
																					APPR. RJB	DATE 2-2-90		

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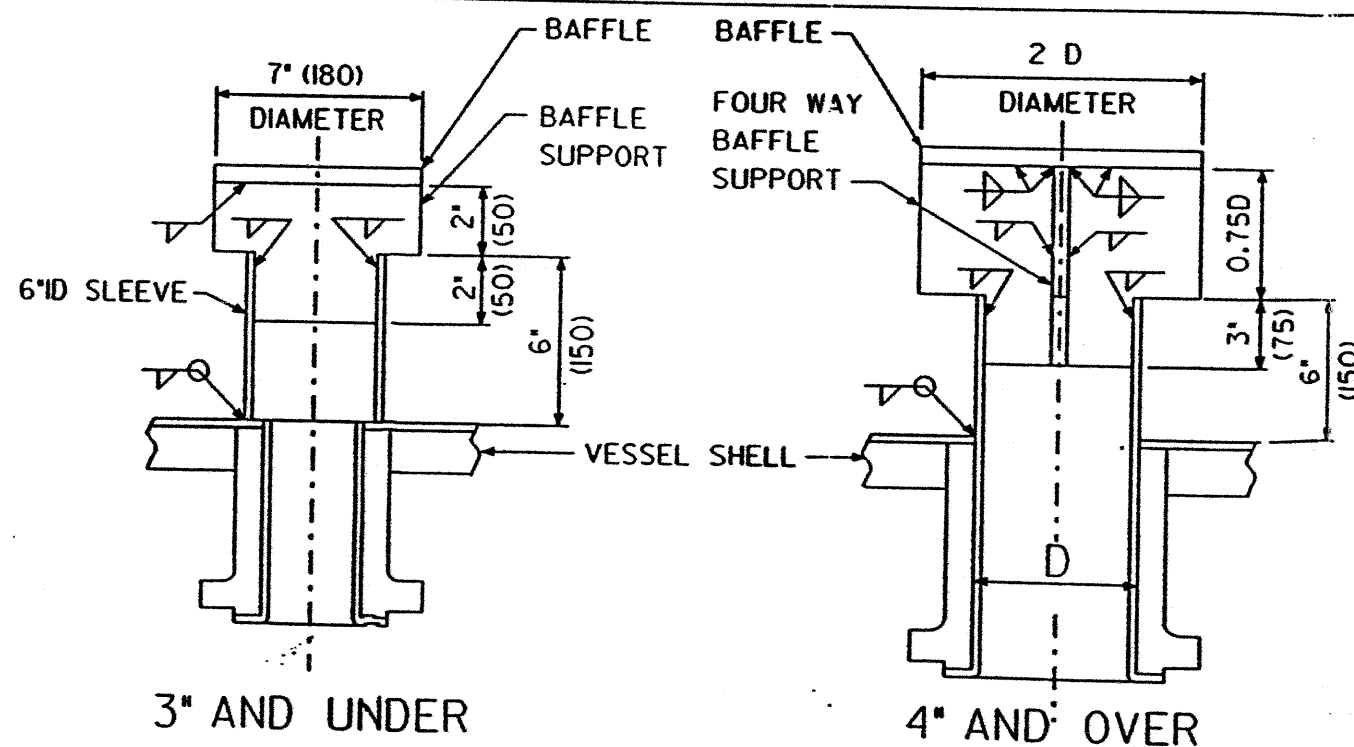
APPENDIX 9 Continued



ELEVATION (NOTE-5)
UNLINED VESSELS



ELEVATION (NOTE-5)
CONCRETE LINED VESSELS



ELEVATION (NOTE-5)
ALLOY LINED VESSELS

NOTES:

1. UNLINED VESSEL BAFFLE PLATES TO BE $\frac{1}{4}$ " (6) CARBON STEEL. PIPE TO BE STANDARD WALL CARBON STEEL.
2. ALLOY OR CONCRETE LINED BAFFLE AND SLEEVE MATERIAL SHALL BE $\frac{3}{16}$ " (5) PL. SAME MATERIAL AS NOZZLE LINING.
3. DETAILS, DIMENSIONS AND NOTES IN PROJECT SPECIFICATION-VESSELS TAKE PRECEDENCE OVER THOSE SHOWN HEREON.
4. DIMENSIONS IN PARENTHESIS ARE MILLIMETERS
5. ELEVATION VIEWS SHOULD BE INVERTED WHEN INLET NOZZLE IS ON TOP OF VESSEL.

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BAFFLE DISTRIBUTOR FOR
HORIZONTAL VESSELS

REV.	DR.	CK.	APPR.	DATE	REV.	DR.	CK.	APPR.	DATE	REV.	DR.	CK.	APPR.	DATE	REV.	DR.	CK.	APPR.	DATE	PROJECT	DR.	BGA	CK.	RRN	DWG NO.	REV.
1	BGA	WGM	WGM	11 DEC 90																8005	APPR.	RJB	DATE	05 FEB 90	C17059-B	1

ENGINEERING DESIGN SEMINAR

SEPTEMBER 6, 1994 – NOVEMBER 11, 1994

MESH BLANKETS

MESH BLANKETS

Utility

In any operation or process where a gas or vapor is generated from a liquid, or where gas passes through a liquid, complete separation of the two phases never occurs. The gas will entrain or carry with it varying quantities and sizes of liquid droplets. A similar condition results when a liquid condenses from a gas. This entrainment or liquid carry-over is a true liquid in the form of minute, dispersed droplets which cannot settle out by gravity due to the velocity of the carrier gas or vapor.

Liquid entrainment is present in practically any liquid-gas processing vessel and often occurs at several locations or stages within a single vessel. In some cases the entrained liquid, which may contain minerals, salts, dirt and other contaminants, is carried on into subsequent processing operations where it can cause reduced yield, poor quality of product or damage to downstream processing material or equipment. In other cases, the entrained liquids, unless removed, are carried off in the effluent and are a direct loss to the operation as well as a polluting agent to the surrounding atmosphere.

Several types of impingement separators have been used in an attempt to minimize the entrainment of liquid in the carrier gas or vapor:

1. Knitted mesh blankets
2. Staggered baffles or channels
3. Perforated plates

Except in systems where sticky, or very tacky solids are present and the danger of plugging exists, knitted mesh blankets are very effective entrainment eliminators. In the case where such solids are present, staggered baffles or perforated plates should be less subject to plugging due to the larger holes or spacing.

There are numerous factors why knitted mesh blankets are considered to be the most versatile of the impingement separators:

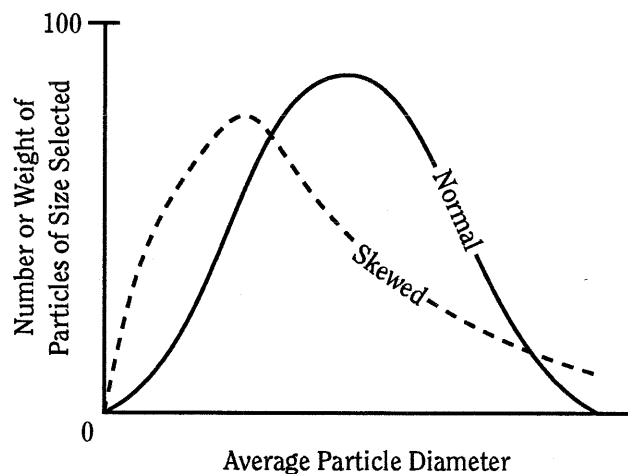
1. High removal efficiency through a wide range of operating velocities.
2. Adaptable to a wide variety of process operations.
3. Low pressure drop.
4. Low initial installed cost.
5. Low operational and maintenance cost.
6. Adaptable to existing vessels as well as to new equipment.

Theory

As a vapor or gas separates from a liquid phase, some entrainment takes place; the greater the velocity of separation, the greater the amount of entrainment. Particle sizes are controlled by the physical properties of the liquid such as density, surface tension and viscosity as well as velocity. The distribution of particle sizes can be represented by a probability curve (Figure 1).

Figure 1

Droplet Size Probability Distribution



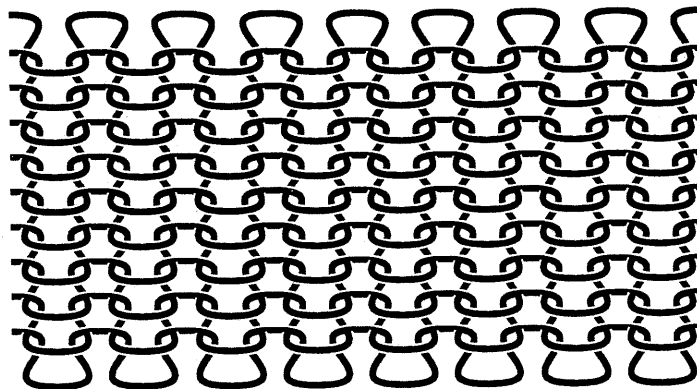
EDS-R00-3401

Sometimes due to special phenomena, some portions of the probability curve are cut off or extended. In any case, to obtain particle size distribution in an operating entrainment system is quite difficult, even on an experimental level. Particle size is usually estimated as an average droplet size and a normal probability of distribution is assumed. Limited changes in operating conditions (velocities, temperatures, pressures, molecular weights, feeds etc.) can have a profound effect on both particle size as well as the distribution. However, mesh entrainment eliminators will compensate for these changes and will remove droplets at a high efficiency. When droplet sizes fall below a size of three microns, the knitted mesh blanket is not always recommended. However, it can precede the fine particle remover (e.g., electrostatic precipitator) and relieve this equipment of a large percentage of its burden.

Since 1944, fine diameter wires interlocked by a knitting operation have been used to form a pad with a high free volume, usually between 95 and 99 percent, in order to minimize pressure drop (Figure 2).

Figure 2

Typical Layer of Wire Mesh

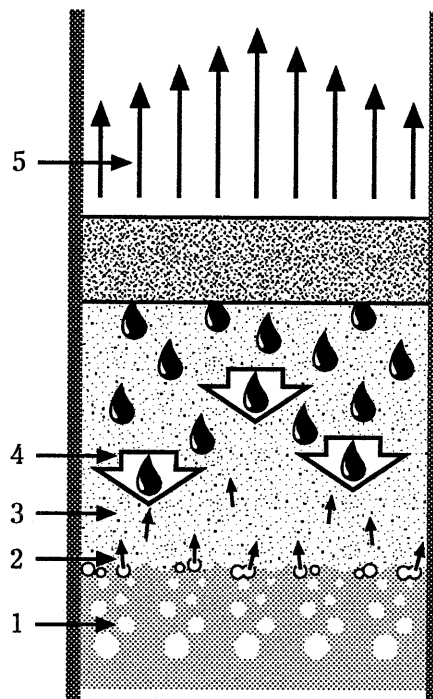


EDS-R00-3402

The individual layers of wire are arranged to provide maximum impingement area, usually between 45 and 120 square feet per cubic foot.

In the operation of a mesh blanket three different forces are in action. The velocity force of the vapor tends to carry the liquid droplet upward. Impingement stops the upward motion of the particle and it is momentarily held there. However, the smooth convex surface of the wire does not present the type of surface which easily remains wetted, with the result that the liquid droplet almost immediately flows downward along the wire surface to a point where the adjacent wires provide capillary space. These spaces may be considered as collecting stations for the liquid. Coalescing occurs and the force of gravity tends to pull the now larger drop downward. The third force is that of surface tension which is not important except at the lower surface of the mesh blanket. Here surface tension holds the liquid until drops are formed which are large enough so that the force of gravity exceeds the combined force of velocity and surface tension with the result that the large drop is torn away from the mesh surface. These drops are then of sufficient size so that they will continue to fall against any reasonable velocity (Figure 3).

Figure 3



EDS-R00-3403

1. Vapor disengaging from liquid creates fine droplets.
2. Rising vapor carries liquid entrainment.

3. As the vapor passes through the mesh blanket, the droplets impinge on the wire surface and coalesce into large drops.
4. Large liquid drops fall free.
5. As the vapor leaves the mesh blanket it is almost entirely free of entrainment.

Size

Given a low enough velocity and sufficient time, most of the entrained liquid in a system would be removed by gravity, but the size of the equipment would be impractical. Like most equipment, moving or stationary, entrainment eliminators operate most efficiently within proper velocity limits. Velocity is an important factor in the sizing of a mesh blanket:

1. If the velocity is below the lower limit, the droplets follow the stream of gas without impinging.
2. If the velocity is at the lower limit, the droplets impinge on the wires due to the change in direction forced on the gas and the liquid runs off the wire.
3. If the velocity is increased above the minimum, a layer of liquid begins to form on the mesh and scrubbing helps to improve further entrainment separation. *Typically 30% of Max. velocity*
4. If the velocity is further increased, the liquid layer gradually increases in depth nearing the exist side of the mesh.
5. If the maximum velocity is exceeded, re-entrainment will occur.

Several factors govern the allowable gas velocity through a mesh blanket for a given set of conditions:

1. Gas and liquid density.
2. Surface tension of liquid.
3. Viscosity of liquid.
4. 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. By starting with the relationship of Stokes Law (separation of particles by gravity) and applying the Souders-Brown correlation, a convenient means for calculation of the allowable vapor velocity for mesh entrainment eliminators is given by the equation:

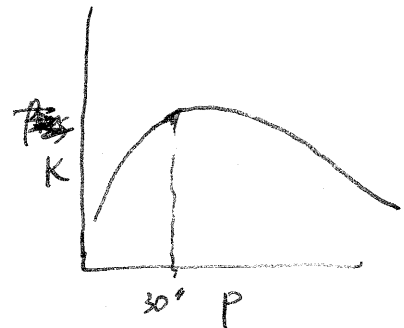
$$V = K \left[\frac{d_l - d_g}{d_g} \right]^{0.5}$$

where

- V = Optimum allowable velocity, ft/sec
 d_l = Density of liquid (lb/ft³) at flowing conditions
 d_g = Density of vapor (lb/ft³) at flowing conditions
 K = Values based on system pressure

Pressure (In of Hg Absolute)	K
Less than 1"	0.17
1"	0.17
5"	0.23
10"	0.28
20"	0.32
30"	0.35

Pressure (psia)	K
15	0.35
50	0.34
100	0.32
200	0.31
300	0.30
500	0.28
1000	0.27
Greater than 1000	0.27

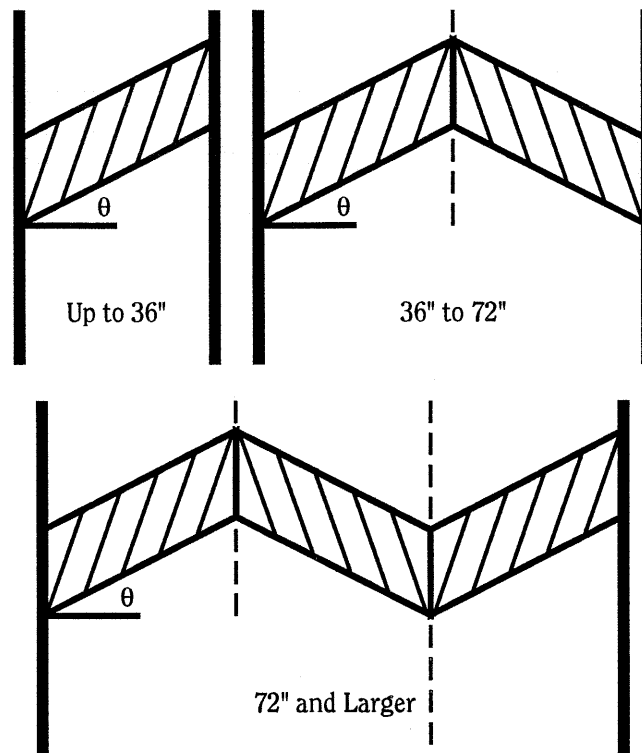


The allowable velocity determined from the equation may then be used to calculate the design velocity. For droplets larger than 15 microns, the velocity range at which efficient separation is accomplished is a very wide, usually 30 to 110 percent, with an average of 70 percent of the calculated optimum allowable velocity. For smaller droplets, less than 15 microns, the velocity for effective separation narrows from 50 to 110 percent, with an average of 80 percent, of the calculated optimum allowable velocity. Such wide velocity flexibility permits the mesh to accommodate wide surge conditions or changes in the previously mentioned factors which govern allowable velocity.

In order that the design velocity may be achieved it may be necessary to decrease the vapor opening in a vessel, provide for an expanded vapor section outside of the vessel proper or provide a mesh blanket arrangement with extended surface within the vessel (Figure 4).

Figure 4

*Extended Surface Arrangements
for Various Size Ranges*



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When entrainment eliminators are installed at angles other than the horizontal, the classic pattern of normal operation, loading and flooding which is typical as vapor velocity increases, no longer applies. As the angle of installation is increased more and more from the horizontal, the increase in pressure drop normally found at the flooding point becomes less pronounced.

For entrainment eliminators installed at angles no greater than 45 degrees from the horizontal, the allowable vapor velocity can be calculated by using an equation similar to that previously shown:

$$V = K_{\theta} \left[\frac{d_l - d_g}{d_g} \right]^{0.5}$$

where V , d_l , d_g and K are previously defined

$$K_{\theta} = K + 0.3 \sin \theta$$

where θ is the angle of mesh to vessel wall as shown in Figure 4.

The design velocity, based on the appropriate droplet size range, is the superficial vapor velocity in the vessel.

Mesh blankets for coalescing in liquid - liquid separation are used to shorten settling time. These blankets are usually designed for horizontal or vertical velocities of 1 to 3 feet per minute.

Efficiency

Since the droplets which are entrained are of varying sizes as previously discussed, there are always small droplets present. In addition, if the vapor leaves a liquid phase which is at its boiling point or bubble point, or the vapor is at its dew point, nuclei of small micron size are formed on slight temperature reductions.

In most industrial applications, droplet size is not known and measurement may be impossible or impractical. Therefore, droplet size must usually be estimated based upon the type of mechanism which generates the entrainment. The following broad generalizations may be used:

SPRAY - 20 microns and larger. Entrainment from low energy input contact devices such as distillation columns, low pressure spray nozzles, evaporators, etc.

MIST - 3 to 20 microns. Lube oil from compressors and high energy spray nozzles.

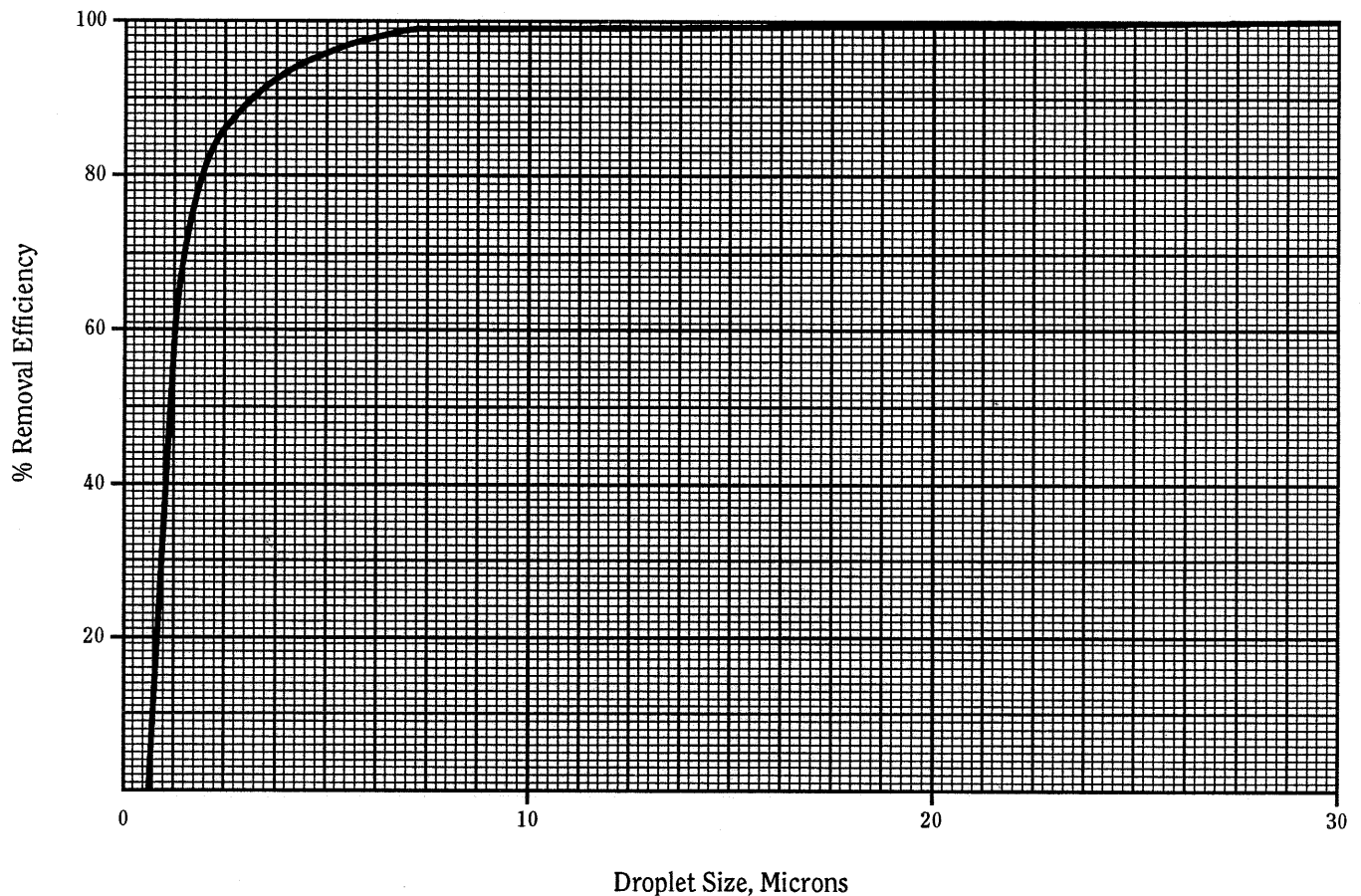
FOG - 3 microns and less. Chemical reactions and condensation from saturated gas streams.

A properly designed entrainment eliminator is able to achieve separation efficiencies of better than 99.9 percent over a wide range of operating conditions. In most industrial applications, residual entrainment of from 1 to 4 parts per million is acceptable and in most cases this level of performance is obtained with the proper thickness of mesh blanket. The high efficiency of the mesh blanket is due to its ability to take advantage of various physical phenomena such as gravity, impingement, centrifugation, coalescing and scrubbing.

Figure 5 shows typical separation efficiencies for a 6 inch thickness of Style B mesh blanket operating in the range of 4 to 12 feet per second.

Figure 5

Style B, 6" Thick Mesh Blanket; Velocity Range 4 to 12 Feet/Second

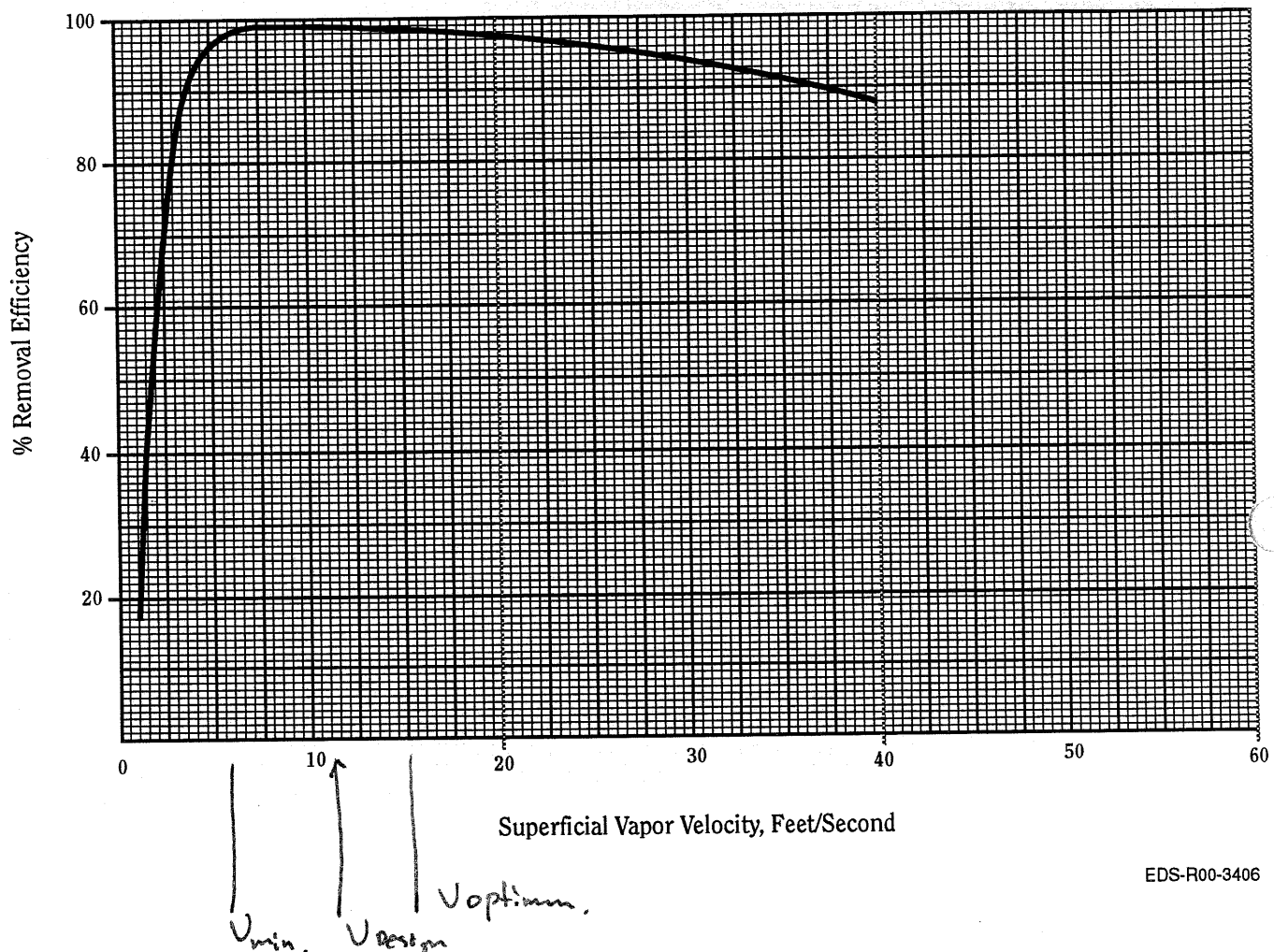


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Figure 6 shows typical separation efficiencies for a 6 inch thickness of Style A mesh blanket removing entrainment in a salt water evaporator.

Figure 6

Style A, 6" Thick Mesh Blanket; Salt Water Evaporator



EDS-R00-3406

Pressure Drop

The pressure drop in a mesh blanket varies considerably depending on the approach to re-entrainment conditions. At the lower velocity limit when the particles collect on the wires, coalesce, run down and drop off the mesh, the pressure drop is at its minimum. It is then essentially similar to that of a vapor passing through a dry packing. Because of the high percent of voids and short equivalent length of travel, the pressure drop is very low. Heavy entrainment loads at this low velocity still leave much free space and consequently still result in low pressure drop.

As the velocity increases, a condition is reached where the liquid run-off is inadequate and an equilibrium is reached at a given depth of liquid in the mesh. This depth increases with greater velocity and also greater loading until the point of re-entrainment is reached. This is the point of optimum allowable velocity and consequently the point of greatest pressure drop.

The pressure drop through a dry wire mesh blanket may be calculated by the equation:

$$\Delta P_D = \frac{0.193 f_c t a d_g V_{act}^2}{g_c e^3}$$

Where:

ΔP_D = Pressure drop across the mesh blanket with no entrainment, inches of water

f_c = Friction factor, dimensionless (Figure 7)

t = Thickness of mesh blanket, ft

a = Surface area, ft²/ft³

d_g = Gas density, lb/ft³

g_c = Gravitational constant, 32.2 ft lb_m/lb_f s²

e = Void fraction of mesh blanket

V_{act} = Actual superficial gas velocity, ft/s

Since the total pressure drop across an operating mesh blanket is the sum of the dry pressure drop plus the additional pressure drop caused by the liquid loading within the mesh, the total pressure drop may be determined by the equation:

$$\Delta P_T = \Delta P_D + \Delta P_L$$

where:

ΔP_T = Total pressure drop across the mesh blanket with entrainment load, inches of water

ΔP_D = drop across the mesh blanket without entrainment, inches of water

ΔP_L = Pressure drop across the mesh blanket contributed by the liquid load, inches of water (Figure 8)

In almost all cases the pressure drop of a normally operating mesh blanket will be about 1 inch of water or less which is negligible for all but very low pressure applications. An approximation of operating pressure drop may be found by using the experience factor that the pressure drop at the calculated optimum allowable velocity is usually 1.5 inches of water and the pressure drop varies with the square of the gas velocity, giving the following equation:

$$\Delta P_T = 1.5 \left(\frac{V_{act}}{V} \right)^2$$

where:

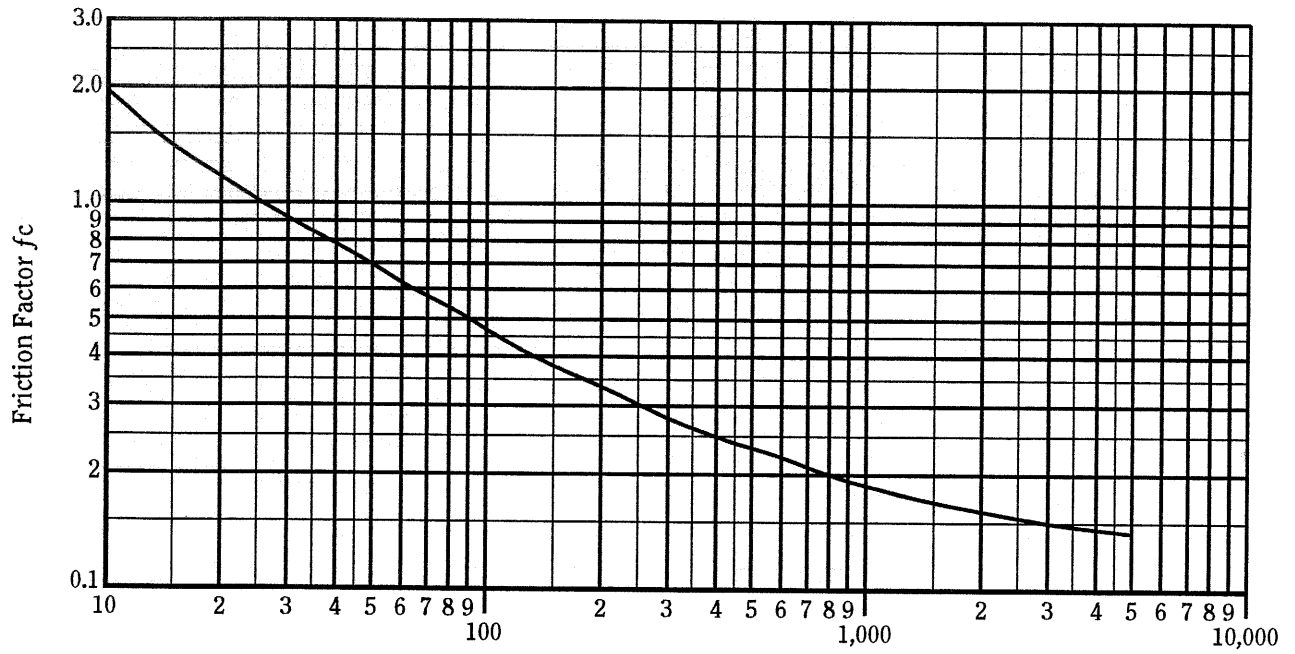
ΔP_T = Total pressure drop across the mesh blanket with entrainment load, inches of water

V_{act} = Actual superficial gas velocity, ft/s

V = Optimum allowable velocity, ft/s

Figure 7

Friction Factor vs Reynolds Number for Mesh Blanket

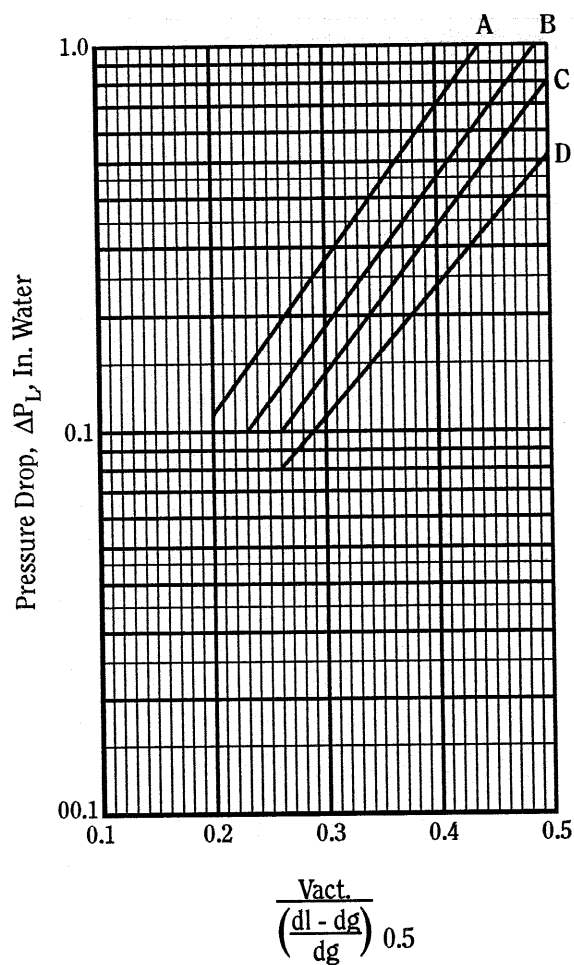


$$\text{Reynolds Number (Re)} = \frac{dg \text{ Vact.}}{a \mu}$$

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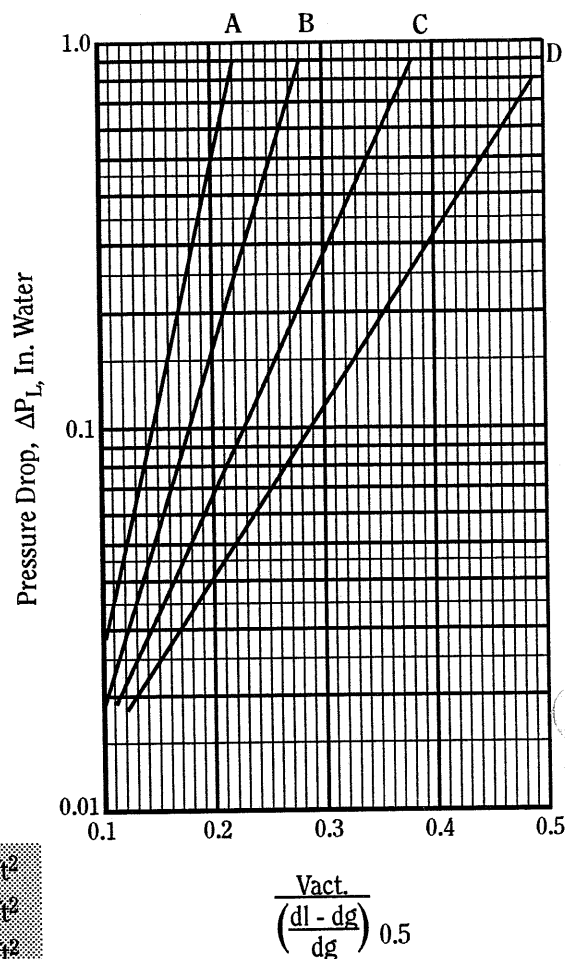
Figure 8

Pressure Drop for Entrainment Load



Style B, 6 in thick mesh blanket

A	2200 lb/hr-ft ²
B	935 lb/hr-ft ²
C	160 lb/hr-ft ²
D	16.5 lb/hr-ft ²



Style C, 6 in thick mesh blanket

EDS-R00-3408

Types

As generally used, the knitted wire mesh entrainment eliminators consist of a bed, usually 4 to 12 inches deep, of fine diameter wires interlocked by a knitting operation to form a wire mesh pad or blanket. The wide range of wire diameter and mesh construction have been combined to form many styles of mesh blankets. From a practical viewpoint, these numerous styles can be grouped into three basic categories:

Style	Wire Diameter (In)	Density (lbs/ft ³)	Surface Area (ft ² /ft ³)	Voids (%)
A	0.011	9	85	98.0
B	0.011	5	45	99.0
C	0.011	12	110	97.7

Style A - is a general purpose mesh used when there are no special requirements.

Style B - is used where fouling such (such as coking) or solids are probable.

Style C - is heavy duty, general purpose mesh used where excellent separation efficiency is required.

Styles A and C consist of individual crimped layers, each one of which is actually a nested double layer. Style B is a herringbone type of arrangement where the crimp directions are alternated. This style not only increases the percentage of voids for the same wire surface, but minimizes the sheltering of one wire behind another, as in the nested double layer construction.

For installations of mesh blankets other than in the vertical position, a six inch thickness is recommended. For mesh blankets installed in the vertical position, two six inch thickness are recommended and arranged so that the joints do not coincide.

FABRICATION AND INSTALLATION

Construction

Mesh blankets can be fashioned to accommodate almost any configuration as well as any limitations of openings and special vessel entry and positioning requirements. The basic construction material is a double layer of knitted mesh fabric. Crimped into one of several specific patterns and sometimes refolded, this double layer is assembled into one of two basic types of pads. Winding the layers into circular pads forms a one-piece entrainment separator for use in small vessels or areas. Stacking

12-1/4 inch wide layers forms a sectional type entrainment separator for easy installation through manholes in large vessels.

Support

The usual method of support is to weld brackets or a support ring to the inside of the vessel shell. The support ring should be two to three inches wide, depending on the vessel diameter, with 1/4 inch diameter holes on approximately four to five inch centers to accommodate the tie wires. (Figures 9, 10 and 13). Other methods of fastening the grid to the support have been developed for cases where tying is not desirable or possible (Figure 12).

Support grids have been developed which are light weight, with a maximum of open area to minimize pressure drop.

For coiled mesh blankets up to 24 inches in diameter a cross-bar type of grid is recommended if the vessel access opening is large enough. This grid is made up of two one inch by 1/8 inch bars placed at right angles with a vertical bolt welded at the intersection. The wound mesh unit is placed on the grid and a nut or clip is fastened to the bolt to hold the unit in position (Figure 11).

The coiled or wound type of mesh blanket is usually assembled outside of the vessel and installed as a unit. The blanket diameter is slightly larger than the inside diameter of the vessel or container which provides for a snug fit and prevents by-passing of the gas or vapor.

Where the access opening is less than the size of the mesh blanket, an assembly of sectional pieces can be made. These sections are usually 12-1/4 inches wide, although they can be prepared in other widths if required. (Figure 9). The grids for sectional units are constructed with three one inch by 1/8 inch bars which are spaced 5-1/4 inches on center, making a total width of 10-5/8 inches. The sections of mesh blanket are made in 12-1/4 inch widths which when assembled give a net width of 12 inches. The lengths are pre-cut so that when assembled they will fit snugly into the vessel or container. Grid sections which span more than six feet must be supported by one or more beams depending upon the length of span.

Subway grating perforated plate or other similar supports are not recommended because they obstruct liquid drainage which can result in liquid carry-over and inefficient operation

Wire mesh sections are securely fastened to individual grid sections by vertical staples or rods which extend from the top to the bottom of the blanket section. It is not necessary to tie adjacent sections of the mesh blanket together. Where vapor surges are encountered or in pulsating service, the use of rigid sandwich construction with top and bottom grids is recommended (Figures 12 and 13).

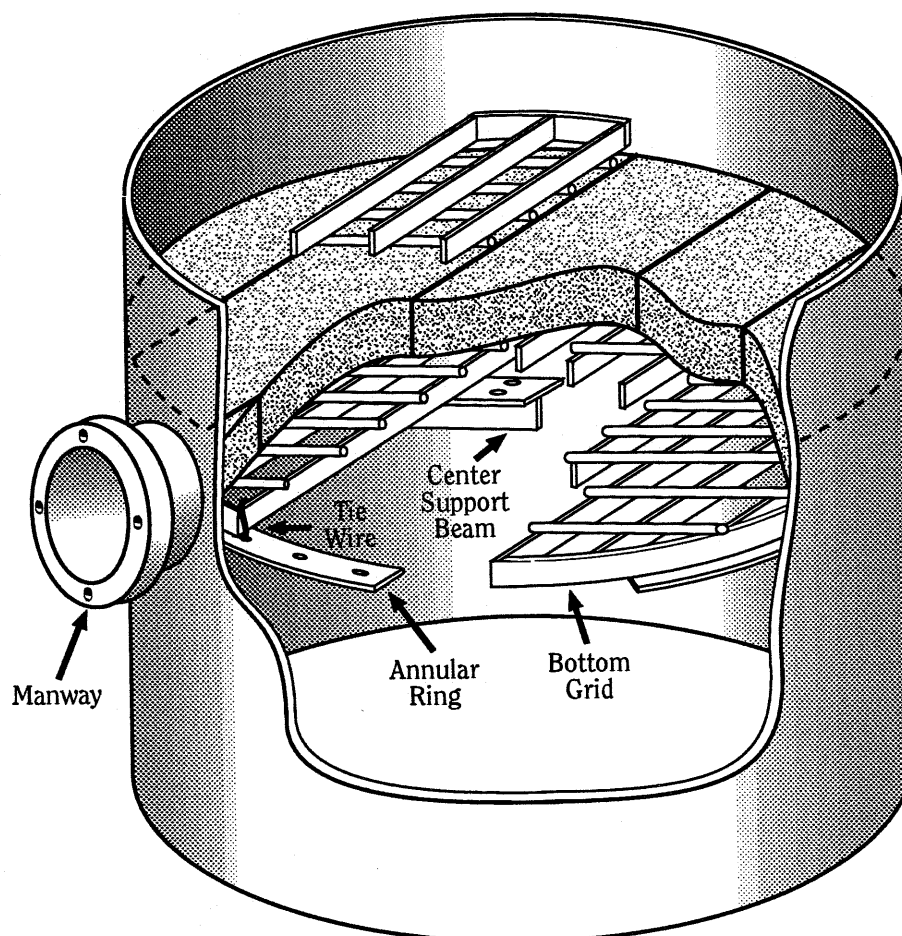
Arrangement

Mesh blankets which are installed horizontally should be located so that the clearance between the feed source and the bottom of the blanket is approximately 50 percent of the blanket diameter or major dimension, with a minimum of one foot and a maximum of five feet. The clearance between the top of the mesh and the vessel outlet should be approximately 35 percent of the blanket diameter or major dimension.

Mesh blankets which are installed vertically should be located so that the clearance between the feed source and the inlet side of the blanket is approximately 50 percent of the blanket diameter or major dimension, with a minimum of one foot and maximum of five feet. The clearance between the outlet side of the mesh and the vessel outlet should be approximately 50 percent of the blanket diameter or major dimension.

Figure 9

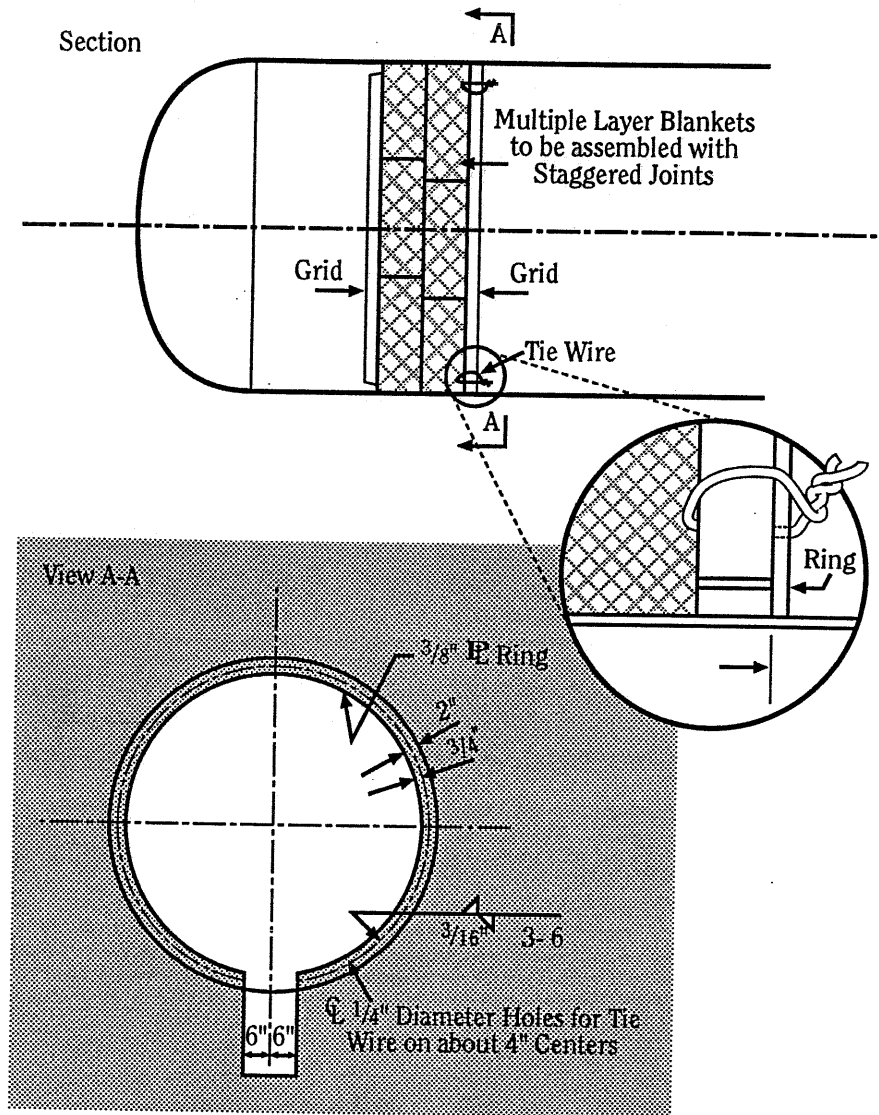
Typical Horizontal Installation of a Sectional Mesh Blanket



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Figure 10

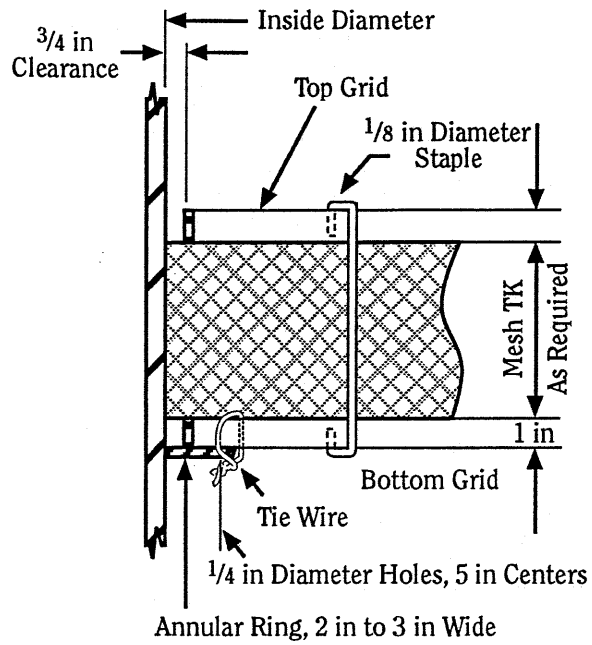
Typical Vertical Arrangement of a Sectional Mesh Blanket



EDS-R00-3410

Figure 11

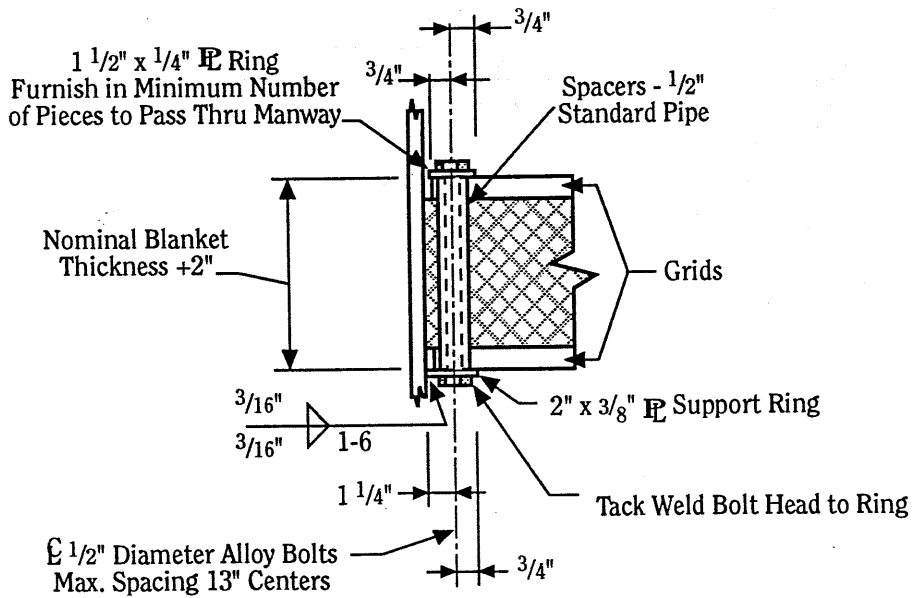
Installation and Removal From Bottom



EDS-R00-3413

Figure 12

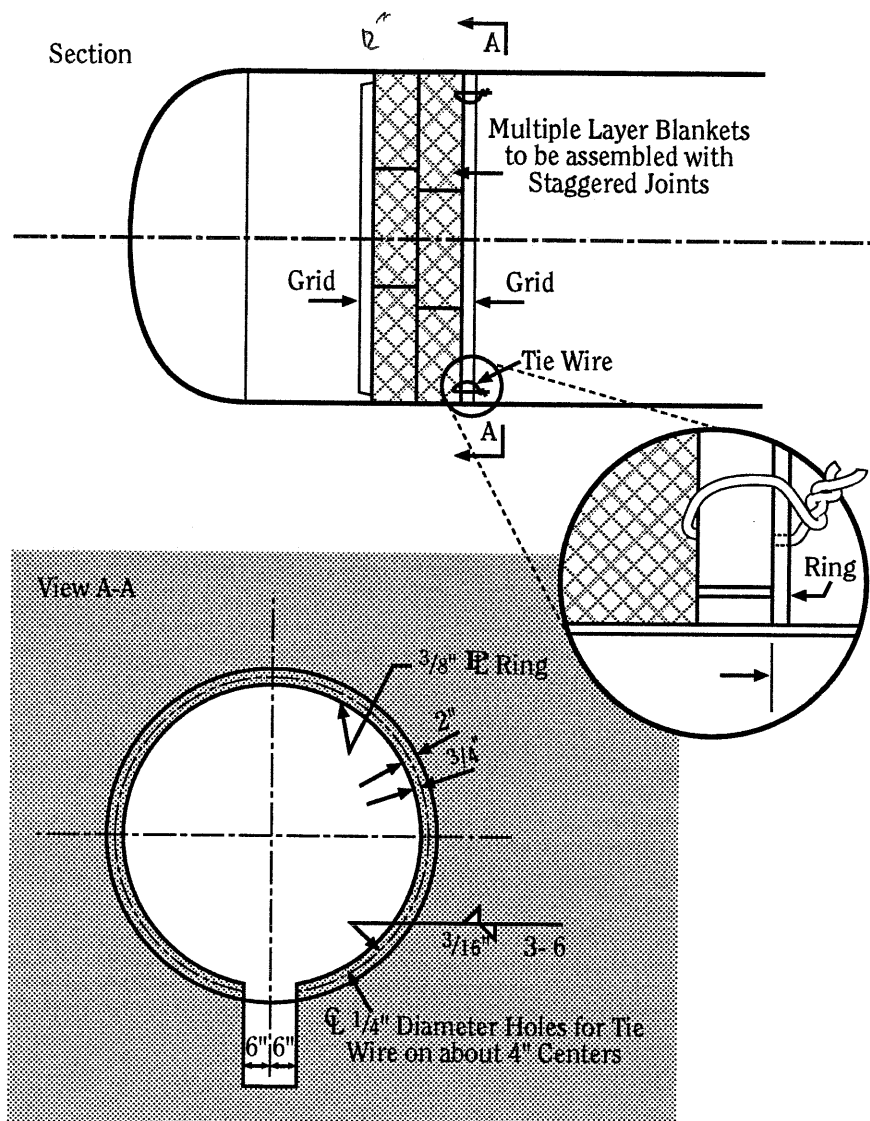
Installation and Removal from Top



EDS-R00-3412

Figure 10

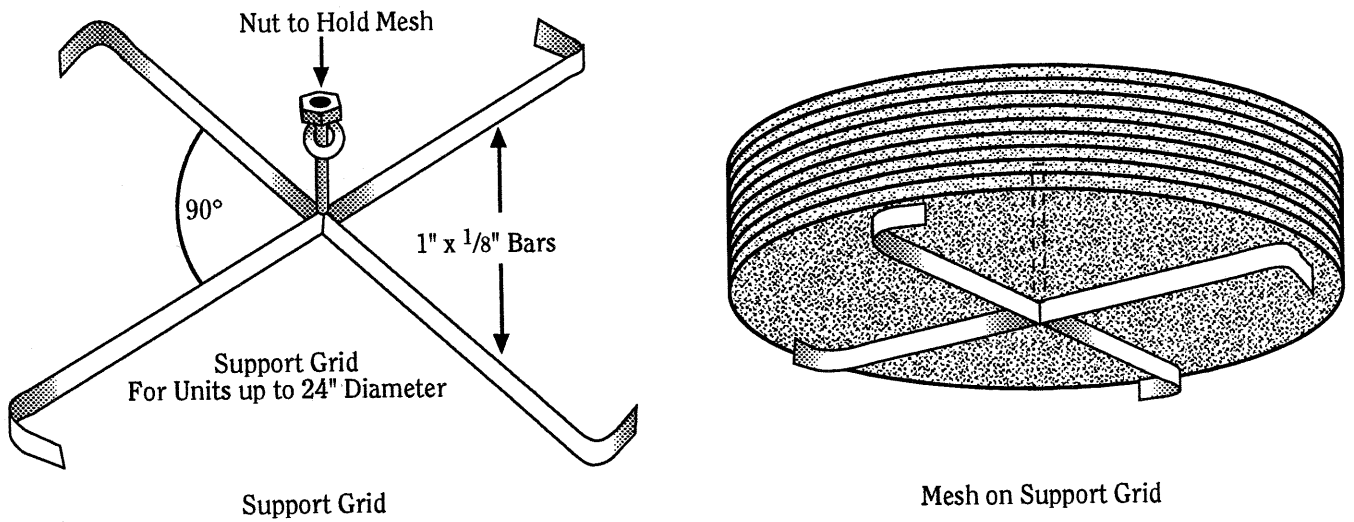
Typical Vertical Arrangement of a Sectional Mesh Blanket



EDS-R00-3410

Figure 13

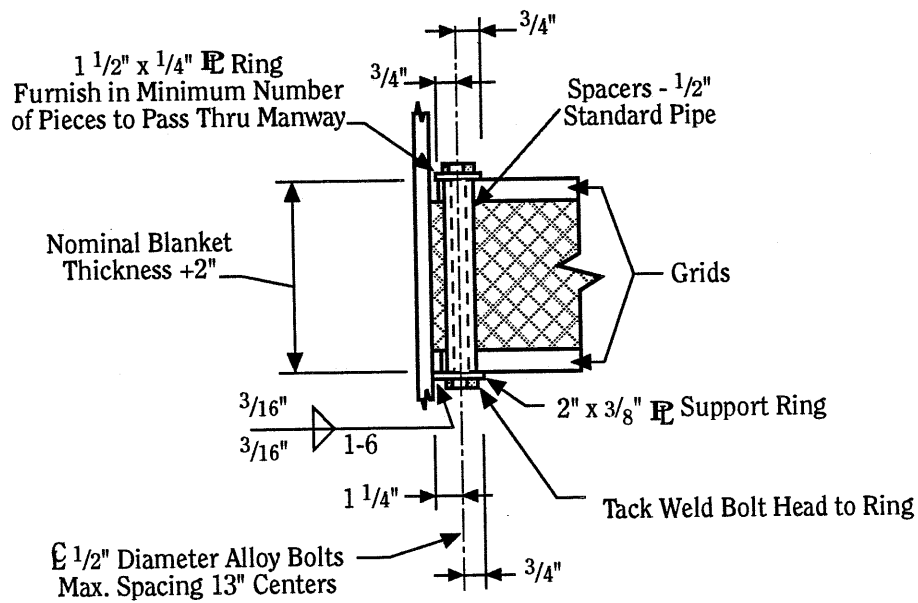
Typical Horizontal One-Piece Mesh Blanket



EDS-R00-3411

Figure 12

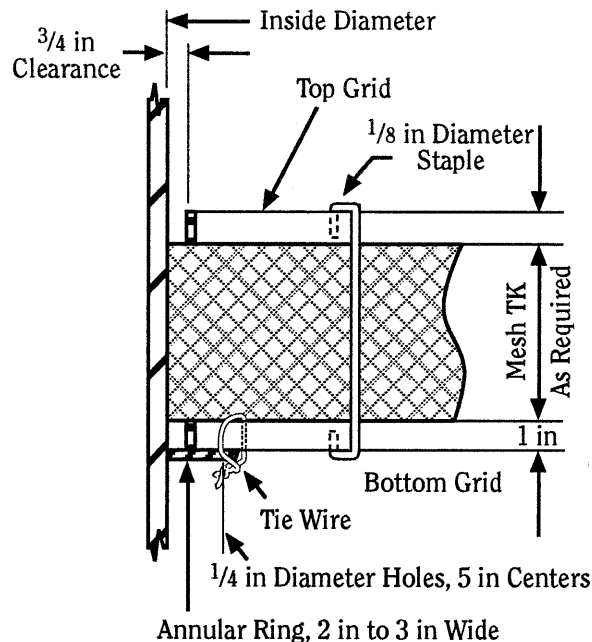
Installation and Removal from Top



EDS-R00-3412

Figure 11

Installation and Removal From Bottom



EDS-R00-3413

Material

The austenitic stainless steels and Monel 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 construction. Polyethylene and polypropylene mesh entrainment eliminators are highly resistant to chemical attack, but generally are limited in use to temperatures below 170° F. Teflon mesh has exceptional resistance to acids, alkalis and organic solvents, and may be used at temperatures as high as 300°F.

Allowable flow rates, pressure drop and efficiency are about the same for non-metallic as for the metallic materials. As would be expected, the mechanical strength of the plastic entrainment eliminators is not equal to that of the wire mesh type. However, the plastic filament is entirely adequate for mist elimination purposes since the structure is only subject to negligible stress during operation. Stainless steel, Monel, Carpenter 20, Hastelloy or Titanium are frequently used as support grid materials for the plastic mesh.

An important and useful development in knitted mesh entrainment 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 multi-filament would be subject to the usual settling which results in excessive pressure drop and disintegration. The potential advantage of the extensive surface of the fine filament is hereby defeated. The composite wire and multifilament construction, however, maintain excellent spatial distribution of the multifilament and eliminates settling by virtue of the support contributed by the interlocking wire mesh framework.

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.

Fabricators

The following are on the UOP approved list of fabricators:

	<u>STYLE IDENTIFICATION</u>		
	<u>A</u>	<u>B</u>	<u>C</u>
"ACS" ACS Disentrainers Division American Copper Sponge Company, Inc. 71 Villanova Street Woonsocket, Rhode Island 02895	4CA	7CA	"Standard"
"DIVMET" Diversified Metal Products Company 1275 Bloomfield Avenue Fairfield, New Jersey 07006	4310	9310	4210
"FLEXIMESH" Koch Engineering Company PO Box 8127 Wichita, Kansas 67208	911	511	1211
"KNITMESH" Knitmesh Ltd. Clements House Station Approach South Croydon CR 2 OYY, Surrey, G. B.	9030	4536	9033
"SCHUYLERNIT" Schuyler Manufacturing Corporation 84 Porete Avenue North Arlington, New Jersey 08032	860	1260	812
"TISSMETAL" Tissmetal Lionel Dupont	270	150	350

22, Chavssee Bocqvaine B. P. 44
51052 Reims Cedex, France

"VICO-TEX"	280	160	380
Industrie Metallurgiche Virgilio Costacurta S.p.A.			
Via Grazioli, 30			
Milano, Italy			

"YORKMESH"	431	931	421
Otto H. York Company, Inc.			
6 Central Avenue			
West Orange, New Jersey 07052			

Nomenclature

a	Surface area, ft^2/ft^3
d_g	Gas density at flowing conditions, lb/ft^3
d_l	Liquid density at flowing condition, lb/ft^3
e	Void fraction of mesh blanket
f_c	Friction factor, dimensionless
g_c	Gravitational constant, $32.2 \text{ lb}_m \cdot \text{ft}/\text{lb}_f \cdot \text{s}^2$
K	System pressure coefficients
K_θ	$K + 0.3 \sin \theta$
ΔP_D	Pressure drop across mesh blanket without entrainment, inches of water
ΔP_L	Pressure drop across mesh blanket contributed by liquid load, inches of water
ΔP_T	Total pressure drop across mesh blanket with entrainment load, inches of water
t	Thickness of mesh blanket, ft
μ	Viscosity, $\text{lb}/\text{ft} \cdot \text{s}$
V	Optimum allowable velocity, ft/s
V_{act}	Actual superficial gas velocity, ft/s
V_d	Design velocity, ft/s

Bibliography

York, Poppele, Chemical Engineering Progress, 59, #6, June 1963

Othmer, Carpenter, A.I.Ch.E Journal, December, 1965

ACS Disentrainer Division
Catalog No. 57

Diversifield Metal Products, Inc.
Divmet Design Manual

Metal Textile Corporation
Catalog