

DESIGN MANUAL

SPD0023ERN-USA
PROCESS DESIGN MANUAL

DRUM

REV.: 2

DATE: 09 Jun 2011



**SAMSUNG
ENGINEERING**

	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page i of ii
DATE: 09 Jun 2011		

Table of Contents

1. SCOPE	1
2. FORMAT	1
3. DESIGN CRITERIA	1
3.1. General	1
3.1.1. Purpose	1
3.1.2. Applications of Vertical and Horizontal Drums	1
3.1.3. Length/Diameter (L/D) Ratio	2
3.1.4. Holding Time.....	3
3.1.5. Vapor-Liquid Separator.....	4
3.1.6. Settling.....	4
3.1.7. Demisters.....	4
3.2. Vapor-Liquid Separator	8
3.2.1. Vertical Separator	8
3.2.2. Horizontal separator.....	9
3.3. Liquid-Liquid Separator	11
3.3.1. Vertical Separator	11
3.3.2. Horizontal Separator.....	11
3.4. Special Vessels.....	12
3.4.1. Dehydrators	12
3.4.2. Steam Drum.....	13
3.4.3. Instrument Air Receiver	15
3.4.4. Fuel Gas Surge Drum	16
3.4.5. Distributor and Baffle	17
3.4.6. Miscellaneous Nozzles	17
4. REFERENCES	18
5. REVISION STATUS	19
6. APPENDIX A: Terminal Velocity and Its Applications.....	20

	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page ii of ii
DATE: 09 Jun 2011		

A-1. Terminal Velocity of a Spherical Fine Particle Settling under the Influence of Gravity 20

A-2. Application to Vertical Vapor-Liquid Separator..... 21

A-3. Application of Equations to Vertical Liquid-Liquid Separators 22

A-4. Horizontal Separators 22

7. APPENDIX B. Tables and Figures 24

Table 3-1: Identification of Wire Mesh Types 24

Table 3-2: "K" Values for Knitted Mesh 25

Table 3-3: Recommended values of K & C for different pressures 26

Fig. 3-1: Typical Mesh Installation in Process Equipment..... 27

Fig. 3-2: Pressure Drop in Wire Mesh Pad⁽⁷⁾ 28

Fig. 3-3: Vapor Velocity Correction⁽⁴⁾ 29

Fig. 3-4: Vertical Vessel with Wire Mesh Pad..... 30

Fig. 3-5: Spacing guidelines to avoid entrainment in mist eliminators ⁽¹⁰⁾ 31

Fig. 3-6: Vertical Vessel without Wire Mesh Pad 32

Fig. 3-7: Horizontal Separator 33

Fig. 3-8: Vertical Liquid-Liquid Separator 34

Fig. 3-9: Horizontal Liquid-Liquid Separator 36

Fig. 3-10: Steam Drum 36

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 1 of 38
DATE: 09 Jun 2011		

1. SCOPE

This manual covers the minimum requirements for the design of drums or vessels.

2. FORMAT

Drum design results can be summarized in the latest revision of data sheet form, Form-C-6110-104AA SEA Rev. __.

3. DESIGN CRITERIA

3.1. General

3.1.1. Purpose

Drums are provided mainly for the following purposes:

- Vapor-liquid Separation
- Liquid-liquid Separation
- Vapor-Liquid-Liquid Separation
- Liquid Storage or surge

Therefore, for optimum construction, the engineer shall design drums with full understanding of their characteristics.

3.1.2. Applications of Vertical and Horizontal Drums

The following guidelines shall be followed in the determination of drum types (whether the drum or vessel should be of a horizontal type or a vertical type).

A. Vertical

- Vertical drums are commonly used where the plot plan area is limited.
- For separation of small amounts of liquid from a gas, vertical vessels are advantageous.
- In cases where the vapor-liquid ratio is large, vertical vessels are advantageous
- In cases where the vapor-liquid ratio is extremely small, the vapor phase volumes of both horizontal and vertical vessels can be reduced to below 50%. Under such

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 2 of 38
DATE: 09 Jun 2011		

conditions, vertical vessels become preferable than horizontal vessels in some cases. Because, the liquid controllability can be kept constant in the vertical vessels.

- In cases where the liquid flow to the vessel fluctuates frequently, vertical vessels are preferable to horizontal vessels.
- Due to higher liquid downward velocity, vertical vessels are preferable for applications of preventing re-vaporization or re-mixing of fluids in vessels.

B. Horizontal

- A horizontal drum is more effective as liquid-liquid separator because it provides more residence time.
- In cases where the vapor-liquid ratio is small, horizontal vessels are advantageous.
- In cases where the three phase separation is required, horizontal vessels shall be used.

3.1.3. Length/Diameter (L/D) Ratio

Normal L/D^1 ratio for vertical separator is in the 2- 4 range while for horizontal separators, the L/D ratio is in 2.5 – 5 range. For semi-ellipsoidal heads the L/D ratio should be 2 and for semispherical heads the L/D ratio should be between 2 and 4. This ratio is typically set by the requirements for disengagement, surge, liquid retention time and operating pressures. The higher the operating pressure and/or material class, the larger the L/D ratio is. For example, the following guidelines can be recommended for horizontal separators.

<u>Operating Pressure, psig</u>	<u>L/D Ratio</u>
0 to 250	3
250 to 500	4
>500	5

¹ Length is based on tangent to tangent length.

	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 3 of 38
DATE: 09 Jun 2011		

Since drums are fabricated of 60 inches width plates in many cases, the inside diameter and tangent-to-tangent lengths shall be specified by increments of 30 inches, such as 60 inches, 90 inches and 120 inches.

Minimum drum size² should be 24 inches inside diameter. For small drums, consideration should be given to using 24 or 30 inches outside diameter pipe.

3.1.4. Holding Time

Refer to SPD0022ERN-USA (Tower), Section.5.4.1 for details.

For a quick estimation of the drum size, the following holding times are recommended for different services. Experienced engineers must be consulted as necessary for certain applications in addition to meeting the requirements of project specifications.

<u>Service</u>	<u>Holding Time</u>
Pump Suction	3 mins
Liquid to a process vessel	3 mins
Furnace feed	10 mins
Liquid for fired reboiler	10 mins
Liquid to storage	2 mins
Feed to exchanger	2 mins
Reflux to tower	5 mins
Pumped recirculation liquid	1 min
Water draws from a boot	3 mins

² Drum may be defined as a piping segment rather than a vessel if size limitations defined by ASME Section VIII can all be met.

	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2
DATE: 09 Jun 2011		Page 4 of 38

3.1.5. Vapor-Liquid Separator

For vapor disengagement, the most commonly used equation is the Souders-Brown equation, which determines the maximum allowable vapor velocity. The equation is given below.

$$V_a = K \sqrt{\frac{\rho_l - \rho_v}{\rho_v}} \quad (\text{Equation 1})$$

Where,

V_a : maximum allowable vapor velocity, ft/sec

K : specified coefficient, ft/sec; see Table 3-3 on Appendix B

ρ_l : liquid density, lb/ft³

ρ_v : vapor density, lb/ft³

If two liquid phases are present, ρ_l is the density of the higher dense phase.

For a horizontal drum, if the drum length is greater than 10 ft, the value K from Table 3-3 should be multiplied by a factor, $\left(\frac{L}{10}\right)^{0.56}$. The K value of 0.5 ft/sec is the upper limit for sizing horizontal separators with wire mesh mist extractors.

3.1.6. Settling

For liquid-liquid separators, the vessel size is set by the settling rate for each phase. Settling rate is calculated in accordance with one of the equations or settling laws as discussed in Appendix A describing terminal velocity.

3.1.7. Demisters

Demisters, sometimes called crinkled wire mesh screens (CWMS), are effective entrainment separators that should be used in relatively clean service. Drum size can be reduced significantly if the service is clean and does not corrode or foul the demister material.

Demisters have both advantages and disadvantages as entrainment separators. They perform well over a wide range of flow (30 to 110 % of

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 5 of 38
DATE: 09 Jun 2011		

design flow capacity). However, they are susceptible to plugging from dusts if the entrained liquid mist collected in the demister is not sufficient to wash down the collected dust. They also provide poor performance when not installed in the horizontal plane, primarily due to uneven distribution, etc.

Some general guidelines for design rating are outlined below:

- Normally the mist eliminators shall be rated 85%.
- Mist eliminators shall be rated 50% in cases where there is a possibility to plugging from dusts.
- Mist eliminators shall be rated 67% in cases where the eliminator has to be installed vertically or sloped.

Adequate plenum space above the pad is necessary to promote even gas flow distribution through the pad. Another consideration that is often overlooked is sufficient separation between the expected high liquid level and the demister. This is especially important in large vessels or vessels where slugging of vapor and/or liquid can occur. If enough clearance is not allowed, wave formation can result in poor de-misting performance. Baffles, vanes or labyrinths can be added to reduce these effects.

Allowable Superficial Velocity

The flow velocity through the mist eliminator shall be calculated by the following equation:

$$v_s = K \frac{DR}{100} \sqrt{\frac{\rho_L - \rho_V}{\rho_V}} \quad (\text{Equation 2})$$

Or

$$K = \frac{100 \cdot V_s}{DR} \sqrt{\frac{\rho_V}{\rho_L - \rho_V}} \quad (\text{Equation 3})$$

Where,

V_s : allowable superficial velocity at wire mesh pad, ft/sec

K : Velocity constant, ft/sec; see Table 3-2 or Table 3-3 on Appendix B

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 6 of 38
DATE: 09 Jun 2011		

ρ_L : Liquid density, lb/ft³

ρ_V : Vapor density, lb/ft³

DR: Design rating specified in percentage (%)

Types of mist eliminators are as shown in Table 3-1. Normally 9 lb/ft³ eliminators should be used. The value "K" should be selected from those shown on Table 3-2.

Vertical vessels whose "K" value is below 0.1, which is 30% of the "K" value (0.35) usually used, does not need a wire mesh pad. Fig. 3-1 (Appendix B) shows various mist eliminator installations in process equipment.

The superficial flow velocity at the mist eliminator should be kept at above a certain value to maintain the efficiency. Regardless of the flow velocity, mist eliminators should be provided when:

- loss of expensive materials must be minimized
- entrainment or carry-over of hazardous matter must be minimized
- subsequent equipment must be protected from the unfavorable effects of splashes entrained in the stream

If the mist eliminators need to be designed for an excessively large size, the vessels should be designed for a horizontal type (see Fig. 3-1).

Pressure drop

Calculations of pressure drop across a mesh pad shall be made in accordance with the relevant vendor literature. Typical pressure drops in wire mesh pads are so small (2 mmHg or less) that they generally will not pose any problem. The total pressure drop across wire mesh is the sum of the pressure drop across the dry mesh plus the additional pressure loss contributed by the liquid load within the mesh. For estimation purposes, the equation may be expressed as:

$$\Delta P_T = \Delta P_D + \Delta P_L \quad \text{(Equation 4)}$$

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 7 of 38
DATE: 09 Jun 2011		

The dry pressure drop, ΔP_D , is calculated as follows:

$$\Delta P_D = 0.193 \cdot \frac{f_c \cdot l \cdot a \cdot \rho_g \cdot U^2}{g_c \cdot \varepsilon^3} \quad (\text{Equation 5})$$

Where:

f_c is a function of Reynolds's number:

$$Re = \frac{\rho_g \cdot U}{a \cdot \mu}$$

f_c , a , ε and ΔP_L are observed from Fig. 3-2.

a : specific surface area, ft^2/ft^3

f_c : friction factor from Fig. 3-2

g_c : gravitational constant, $32.2 \text{ lb ft/lb-force sec}^2$

l : wire mesh thickness, ft

L : liquid mass flow rate, lb/hr ft^2

ΔP : pressure drop across wire mesh without entrainment load, lb/ft^2

ΔP_D : dry pressure drop across wire mesh without entrainment load, inches of water

ΔP_L : liquid load pressure drop, inches of water

ΔP_T : total pressure drop across wire mesh with entrainment load, inches of water

Re : Reynolds number defined by above equation

U : Superficial gas velocity, ft/sec

ε : Void fraction of wire mesh

ρ_G : gas density, lb/ft^3

ρ_L : liquid density, lb/ft^3

μ : viscosity, lb/ft-sec

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 8 of 38
DATE: 09 Jun 2011		

3.2. Vapor-Liquid Separator

3.2.1. Vertical Separator

Refer to Figs. 3-4 and 3-5.

The diameter required for vapor disengaging in vertical liquid-vapor separators is based on the vapor disengagement velocity calculated in Section 3.1.

Some general guidelines for sizing vertical drums are outlined below:

In cases where wire mesh pads are to be provided, attention shall be paid to the fact that the horizontal cross-sectional area will be reduced by the width of the support ring (which is usually 2 inches; the inside diameter will be reduced by 4 inches. Refer to Fig. 3-4.

The space above the demister can be kept to a minimum. Recommended minimum value is 12 inches; however, this dimension depends on the configuration of vapor outlet nozzle. Some vendors have special criteria for this dimension. Refer to Fig. 3-4 and 3-5.

Disengaging height (H_d) for a vertical separator is the distance between the top side of the feed nozzle to the bottom of a wire mesh pad or to the top tangent line. Criteria for determination of disengaging heights are as follows:

In case where a wire mesh pad is provided, the value of " H_d " shall be the largest of the following (see Fig. 3-4):

- $H_d \geq 12" + H_v$
- $H_d \geq 18"$ (minimum)
- $H_d \geq 0.25D$ (minimum)

In cases where no wire mesh pad is provided, the value " H_d " shall be the largest of the following (see Fig. 3-5):

- $H_d \geq 18" + H_v$
- $H_d \geq 24"$ (minimum)
- $H_d \geq 0.25D$ (minimum)

Where,

H_d : Disengaging height, inches

	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 9 of 38
DATE: 09 Jun 2011		

Hv : Required height determined by the value "K" from Fig. 3-3,
inches

D: Drum inside diameter, inches

The dimension between the feed nozzle and high liquid level (HLL) shall be the following value as a minimum:

- Nozzle center to HLL 12" minimum

The liquid hold-up volume of a separator could be determined in accordance with Section 3.1.4 or the recommended residence times discussed in SPD0022ERN-USA. If liquid - liquid separation is required, checks should be conducted in accordance with Section 3.3.

3.2.2. Horizontal separator

In order to avoid entrainment of liquid droplets into the vapor stream, the vapor velocity should be checked by Equation 6, where Dp is assumed as 100 microns a basis.

$$V_h = \frac{1.79 \times 10^{-2} L (S_l - S_v)}{H \mu_g} \quad (\text{Equation 6})$$

Where,

V_h : Horizontal settling rate, ft/sec

L : Distance between vapor inlet nozzle and vapor outlet nozzle, ft

H : Height of vapor section (section above the HL), ft

S_l : Specific gravity of liquid

S_v : Specific gravity of vapor

μ_g : Viscosity of vapor, (cp)

The above formulas will be satisfactory for most horizontal separators, because the ratio of vapor load to liquid is small.

Some general guidelines for horizontal drum sizing are outlined below:

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 10 of 38
DATE: 09 Jun 2011		

1) *Vapor Space*

- 2) The minimum vapor space above the high liquid level in horizontal drums should not be less than 20% of the drum diameter or 12 inches, whichever is the greater.

3) *Liquid Level*

The normal liquid level (NLL) is usually set at the center line of the drum.

The low liquid level (LLL) at $0.1D + 5$ inch can be considered as the minimum LLL.

The liquid phase volume should be determined in accordance with Section 3.1.4 or the recommended residence times discussed in SPD0022ERN-USA. If liquid-liquid separation is required, the vessel should be designed in accordance with Section 3.3.

4) *Wire mesh demister*

In some cases, a wire-mesh demister may be installed as shown in Fig. 3-7. For the installation of a wire-mesh demister, refer to Section 3.1.7.

The dimension between the high-liquid level and the underside of the wire mesh pad shall be 6 inches minimum.

5) *Boots*

Boots should be sized for a minimum residence time of five minutes as a guideline. For smaller boots, the diameter should be kept same as the commercial pipe sizes as far as possible.

The length-diameter (L/D) ratio should be between 2 and 5. Operability and sizes of level instruments and equipment should be considered while setting the L/D ratio.

Minimum boot diameters should be 10 inches.

Maximum boot diameters should be $1/3$ of the drum inside diameter. Boot diameters larger than this, if required, should be discussed with experienced mechanical engineers. If the installation of the boot becomes mechanically impracticable, the drum should be designed to

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 11 of 38
DATE: 09 Jun 2011		

be a liquid-liquid separator. The liquid-liquid separator is discussed in Section 3.3 below.

3.3. Liquid-Liquid Separator

For normal liquid droplet separation, droplet diameters ranging from 500 to 1,000 microns are assumed as a guide for the design of vertical separators, and droplet diameters of about 100 microns are assumed, as a guide for the design of horizontal separators. Refer to Appendix A (Equation A-1).

3.3.1. Vertical Separator

For a vertical vessel, the diameter is set by the settling rate of each phase. Calculate the de-entrainment velocity of the light phase (the settling rate of heavy phase droplets from the light phase) and the de-entrainment velocity of the heavy phase (the rate at which the light droplets will rise within the heavy phase). The vessel diameter is then based on the larger of the required area.

The terminal velocity (V_t) of any droplet moving in a medium can be calculated from Stokes' law (Equation A-1).

Typical vertical liquid-liquid separators are shown in Fig. 3-8. Feed nozzles shall be arranged such that the liquid-liquid interface is not disturbed.

3.3.2. Horizontal Separator

The disengagement length is a check of the horizontal vessel design. Generally, the time required for settling, which is equal to the height of the liquid level over the settling velocity, must be less than the time allowed for settling.

The liquid velocity (settling velocity) can be determined by the equation given below, where D_p is assumed to be 100 microns.

$$\frac{L}{V_h} \geq \frac{H_l}{V_t}$$

$$V_t = \frac{1.79 \times 10^{-2} (S_h - S_l)}{\mu_l} \quad (\text{Equation 7})$$

	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 12 of 38
DATE: 09 Jun 2011		

Where,

L/V_h : Time allowed for settling, sec

H_l/V_t : Time required for settling, sec

V_h : Horizontal liquid velocity, ft/sec

V_t : Terminal velocity of the heavier fine particles, ft/sec

L : Disengaging length, distance between the inlet nozzle and outlet nozzle, ft

H_l : Height of the liquid space, ft

S_h : Specific gravity of the heavier component

S_l : Specific gravity of the lighter component

μ_l : Viscosity of the lighter component, cp

Typical horizontal liquid-liquid separators are shown in Fig. 3-9. For boot design, see Section 3.2.2.

3.4. Special Vessels

3.4.1. Dehydrators

Sand filters

The quantity of sand to be packed into a sand filter for a given flow rate is indicated below on the assumption that the particle sizes of the sand range from 8 to 16 meshes.

The ratio of the diameter to the packed height is assumed to be 1:1.

Flow Rate	100 bbl/hr
For Naphtha	75 ft ³ of sand
For Kerosene	150 ft ³ of sand

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 13 of 38
DATE: 09 Jun 2011		

Note : The above values are for non-patented typical sand filters.

Salt filters

The packed height of rock salt for salt filter is 10 ft regardless of the diameter of the vessel involved. The standard flow rates for liquid to be treated are given below, for which the particle sizes of the rock salt are assumed to range from 6 to 10 mm.

Unit	bbl/hr ft ²
Flow rate	5.5

3.4.2. Steam Drum

The size of the steam drum should be determined in accordance with the following items.

As shown in Figure 3-10 a of Appendix, hold-up times for horizontal steam drum should meet the requirements listed below.

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA
DATE: 09 Jun 2011		REV.: 2 Page 14 of 38

- a) The emergency low liquid level (E.L.L.L.) alarm is to be set to a level 12" above the bottom of the steam drum.
- b) Minimum 3-minute holdup should be allowed between E.L.L.L. and L.L.L. (low liquid level).
- c) 5-minute holdup should be allowed between L.L.L. and H.L.L. (high liquid level).
- d) Minimum 3-minute holdup should be allowed between H.L.L., and E.H.L.L. (emergency high liquid level)
- e) H.L.L. should be taken as the center line of the steam drum.
- f) Minimum diameter of the steam drum should be 1,000 mm (40").

As shown in Figure 3-10 (b) of Appendix B, the vapor liquid separation system at the steam outlet nozzle includes the following types.

- a) External cyclone type (to be installed outside the steam drum), This cyclone type can typically reduce the water content in the outlet steam to a maximum extent of 0.5 wt%.
- b) Internal type (to be installed in the steam drum)

Wire mesh:

Wire mesh is used for comparatively low pressure below 140 psig and can remove water in the outlet steam to a maximum extent of 0.5 wt%. The wire mesh is 6" (150 mm) and is commonly made of monel.

Purifier :

Refer to the catalog of the VD Anderson Co., which is represented by Mitsui and Co. in Japan. The purifier can remove water in the outlet steam to a maximum extent of 0.2 wt%. In addition, the purifier can guarantee the maximum allowable total solids in the steam, which is set at 1 ppm.

The guidelines below apply to steam drum nozzles.

- The design shown in fig. 3-10 (c) of Appendix B can be used for cases where the number of inlet nozzles need to be increased.

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 15 of 38
DATE: 09 Jun 2011		

- The fresh water inlet nozzle should be separated from the circulation water outlet nozzle and the blow down nozzles. (Fig. 3-10 (b))
- The area of the holes should be larger than that of the nozzles to reduce the inlet pressure drop. (Fig. 3.11 of Appendix B)
- The blow-down nozzles should be so arranged that the water can be blown down as uniformly as possible from within the steam drum. Continuous blow-down should be withdrawn from immediately below the low liquid level. Intermittent blow-down should be withdrawn from the bottom of the steam drum.

3.4.3. Instrument Air Receiver

The volume of the instrument air receiver should be determined by assuming a proper holding time to meet the plant conditions. Here, the holding time is defined as the time during which the pressure varies from the lower limit pressure under normal operation to the minimum operable pressure.

The volume of the instrument air receiver can be calculated by the equation given below.

$$V_v = Q_v \cdot t \frac{P}{P_1 - P_2} \frac{T}{459.67} \quad (\text{Equation 8})$$

Where,

- V_v : Volume of air receiver, ft³
- Q_v : Required flow rate of air, SCFM
- P : Atmospheric pressure, 14.696 psia @ 60 °F
- P_1 : Lower limit pressure under normal operation, psig
- P_2 : Minimum Operable pressure, psig
- t : Holding time of air, min.
- T : Temperature of air during operation, °R

Generally, P_1 , P_2 and t assume the following values:

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 16 of 38
DATE: 09 Jun 2011		

$P_1 = 100$ psig

$P_2 = 35$ psig (applicable only to instrument air); 70 psig
(Also applicable to process air)

$t = 10$ min.

3.4.4. Fuel Gas Surge Drum

The volume of the fuel gas surge drum can be calculated by the equation given below.

$$V_v = (Q_v - Q_v') t \frac{P T}{(P_1 - P_2)^{459.67}} \text{ (Equation 9)}$$

Where,

V_v : Volume of fuel gas surge drum, ft³

Q_v : Required flow rate of fuel gas, SCFM

P : Atmospheric pressure, 14.696 psia @ 60 °F

*** P_1 : Lower limit pressure under normal operation, psig

** P_2 : Minimum operable pressure, psig

* t : Usable time of fuel gas

T : Operation temperature, °R

Q_v' : Flow rate of fuel gas in ft³/min, which can be maintained, when the largest fuel gas inlet line (the one feeding the largest quantity) is assumed to have been stopped.

The above equation is based on the following assumptions:

1. Fuel gas consumption is fixed.
2. The largest fuel gas source will fail, but gas supplies from all other sources will continue.
3. The fuel gas supply is not backed up. Hence, the consumption must be met by the gas held in the fuel gas surge drum only.

*This value should be determined by the state of readiness to augment the fuel supply in cases where the supply of off-gas from the process is insufficient. Normally, 5 ~ 10 minutes are used.

**The value for P_2 is calculated from the equation given below.

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 17 of 38
DATE: 09 Jun 2011		

P_2 : (Pressure Drop in Burner) + (Pressure Drop in Control Valve) +
(Pressure Drop in Piping)

The burner pressure varies from one fuel to other. However, the generally used pressure is about 20 psig. For P_2 , a pressure range from 30 to 35 psig should be used.

*** The value for P_1 is determined by such factor as burner type, fuel gas composition, etc. For example, a lower limit supply pressure of 60 psig has been used for a refinery.

3.4.5. Distributor and Baffle

Baffles and distributors are used for the following applications:

- ♦ All liquid feed: for one liquid phase
- ♦ All liquid feed: for two liquid phases
- ♦ Vapor-liquid mixed feed

Inlet distributors and/or baffles are provided to carry out separation effectively or to prevent disturbance of the vapor-liquid interface. (See Fig. 3-11). Distributors are typically fabricated of commercial pipes.

Baffles shown in Fig. 3-11 are used for gas containing mist or gas liquid mixture.

3.4.6. Miscellaneous Nozzles

For the following nozzles, see SPD0022ERN-USA, Tower, Section 5.7.

Manhole

LC-LG nozzle

Vent, drain

Vortex breaker

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 18 of 38
DATE: 09 Jun 2011		

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 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 19 of 38
DATE: 09 Jun 2011		

5. REVISION STATUS

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 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 20 of 38
DATE: 09 Jun 2011		

6. APPENDIX A: Terminal Velocity and Its Applications

A-1. Terminal Velocity of a Spherical Fine Particle Settling under the Influence of Gravity

The terminal velocity of a spherical fine particle setting under the influence of gravity can be determined by Stokes' law.

$$V_t = \sqrt{\frac{4gD_p(\rho_l - \rho_v)}{3C_D\rho_v}} \quad (A-1)$$

$$V_t = K \cdot \sqrt{\frac{\rho_l - \rho_v}{\rho_v}} \quad (A-2)$$

Where,

V_t : Terminal velocity, ft/sec or (m/sec)

g : Acceleration of gravity, ft/sec² or (m/sec²)

D_p : Diameter of fine particle, ft or (m)

C_D : Drag coefficient

ρ_l : Density of liquid, lb/ft³ or (kg/m³)

ρ_v : Density of vapor, lb/ft³ or (kg/m³)

K : Entrainment coefficient, ft/sec or (m/sec)

Based on the theory and experimental results, C_D can be expressed approximately as follows. It should be noted that C_D is given as a function of Reynolds number, Re only, where the velocity is the relative velocity of the fine particle to its surrounding fluid.

$$C_D = \frac{24}{Re} \quad \text{for } Re < 2 \quad (\text{Stokes' law})$$

$$C_D = 18.5 Re^{-0.6} \quad \text{for } 2 < Re < 500 \quad (\text{Allen's law})$$

$$C_D = 0.44 \quad \text{for } Re > 500 \quad (\text{Newton's law})$$

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 21 of 38
DATE: 09 Jun 2011		

Substituting these for C_D in Equation A-1³,

$$V_t = \frac{1,488 g D_p^2 (\rho_l - \rho_v)}{18\mu} \quad (Re < 2)$$

$$V_t = \frac{3.49 g^{0.71} D_p^{1.14} (\rho_l - \rho_g)^{0.71}}{\rho^{0.29} \mu^{0.43}} \quad (2 < Re < 500)$$

$$V_t = 1.74 \sqrt{g D_p \frac{\rho_l - \rho_v}{\rho_v}} \quad (Re > 500)$$

A-2. Application to Vertical Vapor-Liquid Separator

1. The value "K" in Eq. A-2 is empirical.
2. Various literature (1), (2), (3), (4) and (7) show recommended values but herein E. E. Ludwig's thought (1) is followed in cases where wire mesh is provided and A. H. Younger's (4) thought ($K = 0.1$ ft/sec) is followed in cases where no wire mesh is provided.
3. Several types of wire-mesh demisters are manufactured. The most widely used ones are given in Table 3-1.
4. Various reports (1), (3), (5) and (7) have been presented with respect to disengaging heights (provided under wire mesh pads for vapor-liquid separation). According to them, disengaging heights of 12 ~ 18 inches are sufficient. In this manual, it is required that disengaging heights should be 18 inches minimum in cases where wire mesh is provided. This height must be corrected for the vapor velocity in each individual case.
5. Provision of baffles must be considered. The reason for this is that the duty of vapor liquid separation in the disengaging zone can be reduced by directing the liquid flow downwards.
6. Also, consideration has been given to avoid the unfavorable effects on wire mesh pad due to the coning of feed stream (8) in cases where no baffle is provided. The same thought has been followed even in cases where no wire mesh is provided.

³ Equations from the SPD0023ERN of SECL have been modified to match GPSA.

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 22 of 38
DATE: 09 Jun 2011		

A-3. Application of Equations to Vertical Liquid-Liquid Separators

Using Allen's and Stokes' equations, the terminal velocity of the heavier particles can be calculated. Typical application of these equations to the separation of water from oil is given in the following tables.

1. $D_p = 400 \sim 500$ microns

Physical Properties of Hydrocarbon		Oil Fraction	Maximum Liquid Velocity	
Sp.Gr.	$\mu(\text{cP})$		ft/sec	m/sec
0.70	0.5	Naphtha	0.1	0.03
0.80	1.5	Kerosene	0.05	0.015
0.85	5.0	Gas oil	0.01	0.003
0.90	10.0	Vac. gas oil	0.005	0.0015

2. $D_p = 1,000$ microns (1 mm)

Physical Properties of Hydrocarbon		Oil Fraction	Maximum Liquid Velocity	
Sp.Gr.	$\mu(\text{cP})$		ft/sec	m/sec
0.70	0.5	Naphtha	0.25	0.08
0.80	1.5	Kerosene	0.13	0.04
0.85	5.0	Gas oil	0.06	0.02
0.90	10.0	Vac. gas oil	0.02	0.005

A-4. Horizontal Separators

The following equation is based on Stokes' equation described in Appendix A-1.

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 23 of 38
DATE: 09 Jun 2011		

$$V_t = \frac{gD_p^2(\rho_h - \rho_l)}{18\mu}$$

Where,

G: Acceleration of gravity (32.2 ft/sec²) or 9.8 m/sec²

D_P: Diameter of the heavier particle (ft) or m

ρ_h: Density of the heavier fraction (lb/ft³) or kg/m³

ρ_l: Density of the lighter fraction (lb/ft³) or kg/m³

μ: Viscosity of the lighter fraction (lb/ft sec) or kg/m sec

Substituting 9.8 m/sec² for g and 100 microns for D_p, converting the densities to specific gravities, and expressing the viscosity in centipoise,

$$V_t = \frac{1,488 g D_p^2 (\rho_h - \rho_l)}{18\mu}$$

$$V_t = 5.45 \times 10^{-3} \frac{S_h - S_l}{\mu} \quad (m/s)$$

$$V_t = 1.79 \times 10^{-2} \frac{S_h - S_l}{\mu} \quad (ft/sec)$$

D_p = 100 microns is based on A. D. Scheiman's report (5). Scheiman states in his report that particles larger than D_p = 3 ~ 100 microns have settling velocities defined by Stokes' equation.



7. APPENDIX B. Tables and Figures

Table 3-1: Identification of Wire Mesh Types

Density lb/ft ³	Surface Area (Note 1) ft ² /ft ³	Void Fraction	Wire Diameter inches	York	Manufacture's Type				Application
					Divmet	Metex	Nihon Mesh	Naniwa Special Mesh	
12	110	0.977	0.011 (Note 3)	421	4210	Xtradense	SL	3311	High efficiency, Relatively clean, Moderate velocity, Use in 4" pad
9 (Note 2)	85	0.982	0.011 (Note 3)	431	4310	Nu- standard	N	3383	Standard efficiency, General purpose, Use in 4" pad
8	140	0.984	0.006	326	3260		SN		Fine mist removal, Use in 4"~ 6" pad
5	46	0.99	0.011 (Note 3)	931	9310	HI- throughput	H	3346	High through-put or low density, for service containing solids or "dirty" material, Use in 6" pad
13.7	275	0.972	5 strand each 0.122mm	-	-	-	T	4060	Very high efficiency, 10" and 12". Vendor recommends for special applications such as fine mists, oil vapor mist.

Note 1: If the mesh is made of nickel, monel or copper, multiply the density values of referenced stainless steel by 1.13.

Note 2 : Normally 9 lb/ft³ mesh is used.

Note 3 : Nihon Mesh Kogyo Co. fabricates 0.254 mm wire

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 25 of 38
DATE: 09 Jun 2011		

Table 3-2: "K" Values for Knitted Mesh

Service Conditions	"K"	General Type Mesh
Clean fluids, moderate liquid load, fits 90% of process situations	0.35 to 0.36	Standard
	0.35	High Efficiency
	0.25	Very High Efficiency
High viscosity, dirty suspended solids	0.40	Low density or Herringbone, high through-put
Vacuum operations;		
2" Hg. abs.	0.20	Standard or
16" Hg. abs	0.27	High Efficiency
Corrosive Chemical	0.21	Plastic coated wire, or plastic strand

For most situations very good performance can be expected for all velocities from 30 to 100 percent of the optimum allowable design velocity. The minimum allowable safe design velocity is 10 percent of the value calculated by the equation. The flooding velocity of the mesh is usually about 120 percent to 140 percent of the maximum allowable velocity.

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 26 of 38
DATE: 09 Jun 2011		

Table 3-3: Recommended values of K & C for different pressures

Typical K & C Factors for Sizing Woven Wire Demisters

Separator Type	K Factor (ft/sec)	C Factor (ft/hr)
Horizontal (w/vert. pad)	0.40 to 0.50	1440 to 1800
Spherical	0.20 to 0.35	720 to 1260
Vert. or Horiz. (w/horiz. Pad)	0.18 to 0.36	648 to 1260
@ Atm. Pressure	0.36	1260
@ 300 psig	0.33	1188
@ 600 psig	0.3	1080
@ 900 psig	0.27	972
@ 1500 psig	0.21	756
Wet Steam	0.25	900
Most vapors under vacuum	0.2	720
Salt & Caustic Evaporators	0.15	540

Fig. 3-1: Typical Mesh Installation in Process Equipment

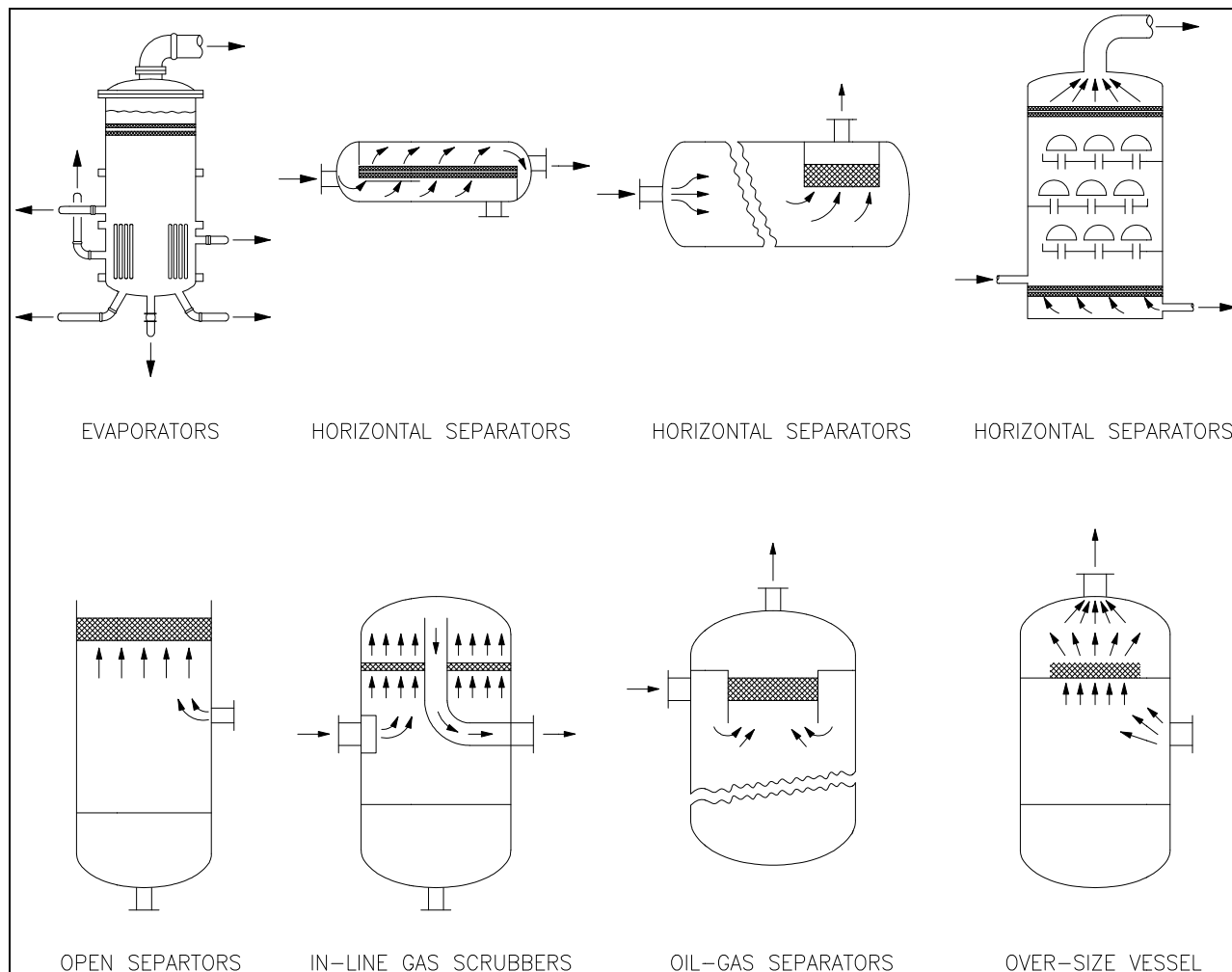
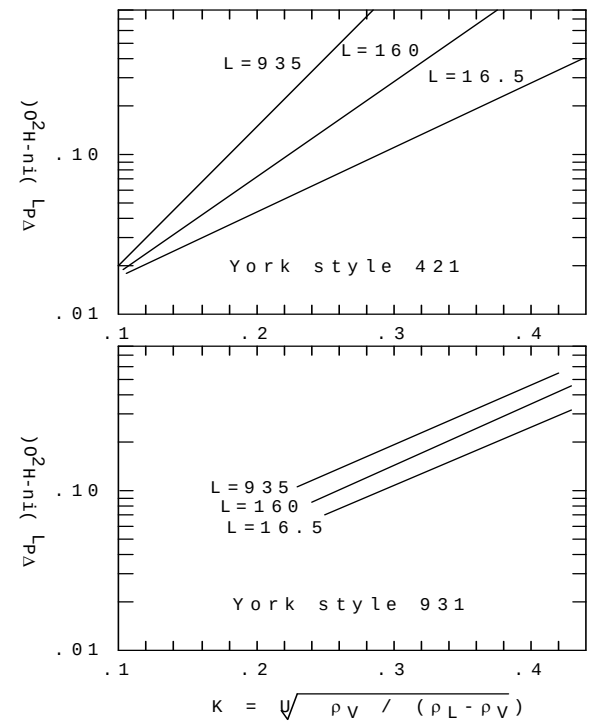
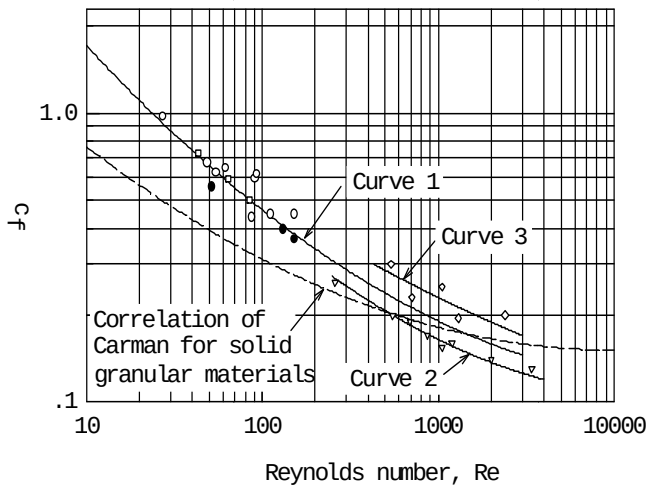


Fig. 3-2: Pressure Drop in Wire Mesh Pad⁽⁷⁾

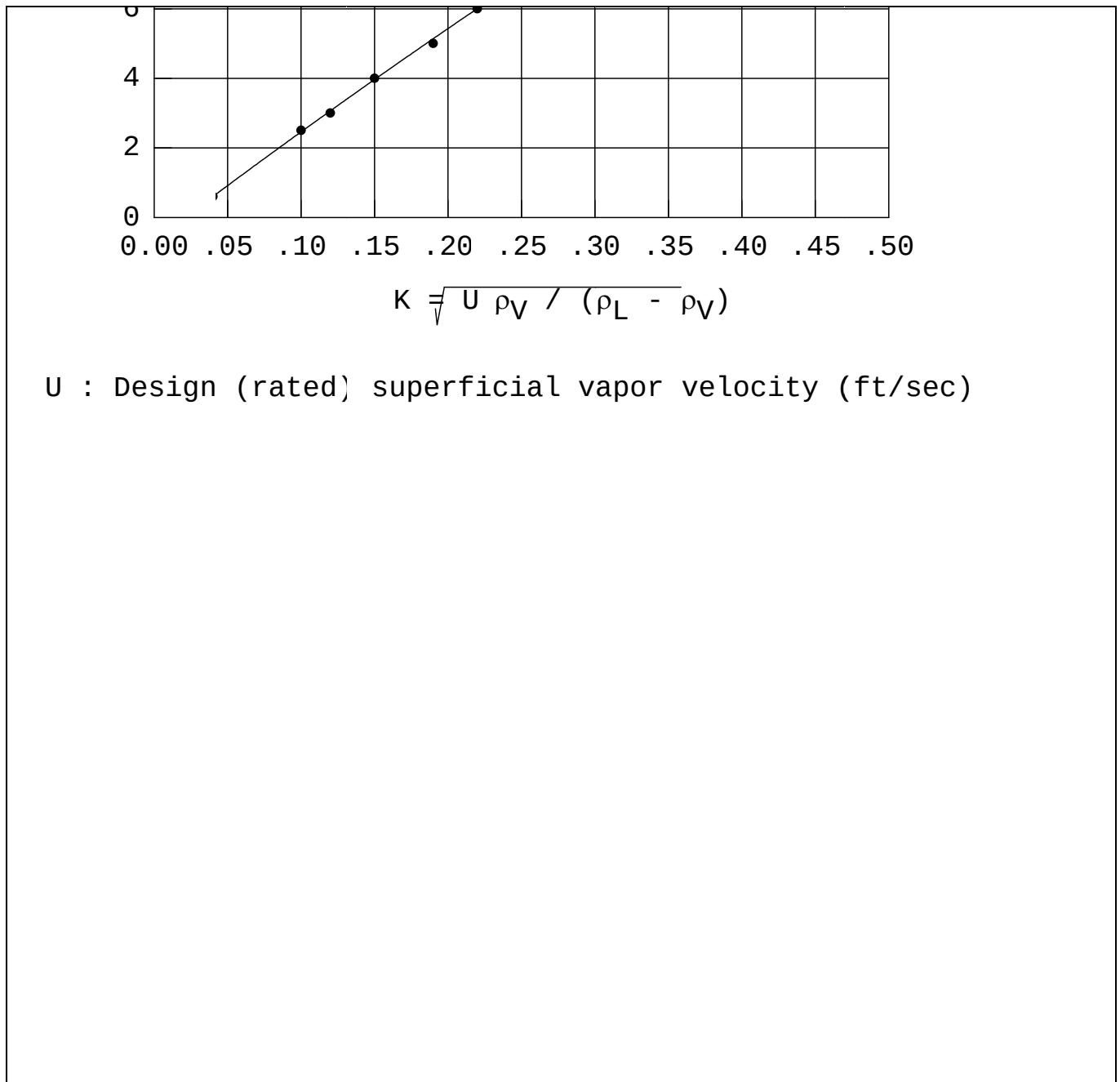
a) Friction factor for wire mesh entrainment separator without entrainment load



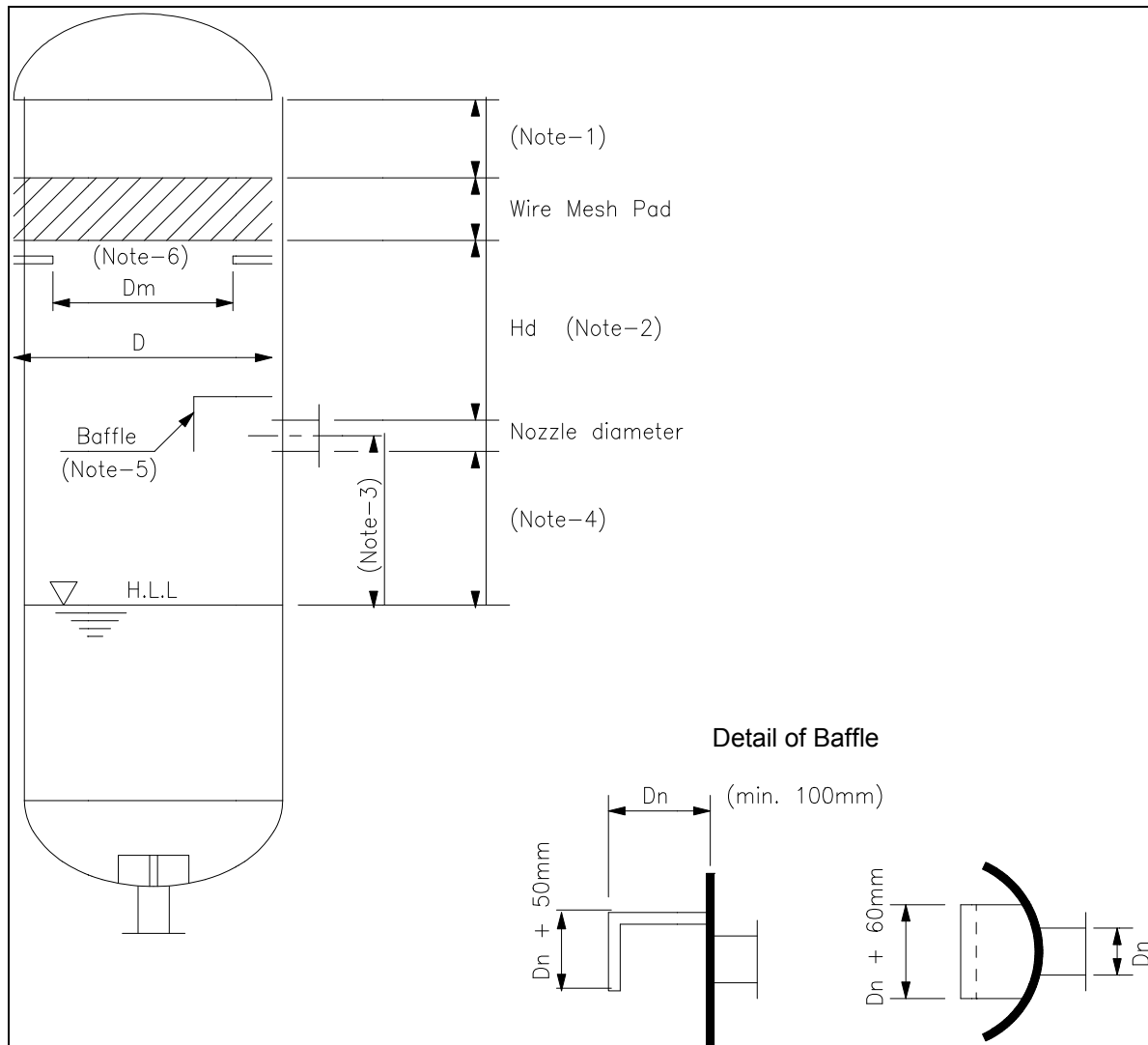
Note:

- ♦ Use curve-1 in the figure (a).
- ♦ See also Table 3-1 for the void fraction and the specific surface area.

b) Pressure drop correction for entrainment load

Fig. 3-3: Vapor Velocity Correction⁽⁴⁾


$$K = U \sqrt{\rho_v / (\rho_L - \rho_v)} \quad (\text{ft/sec})$$

Fig. 3-4: Vertical Vessel with Wire Mesh Pad


(Note 1) Minimum 300 mm (12 inches)

(Note 2) Of the following, the largest value shall be used:

$H_d \geq 12" + H_v$ (H_v ; from Fig. 3-3)

$H_d \geq 18"$

$H_d \geq 0.25D$ (D = Drum diameter, inches)

(Note 3) Minimum 300 mm (12 inches)

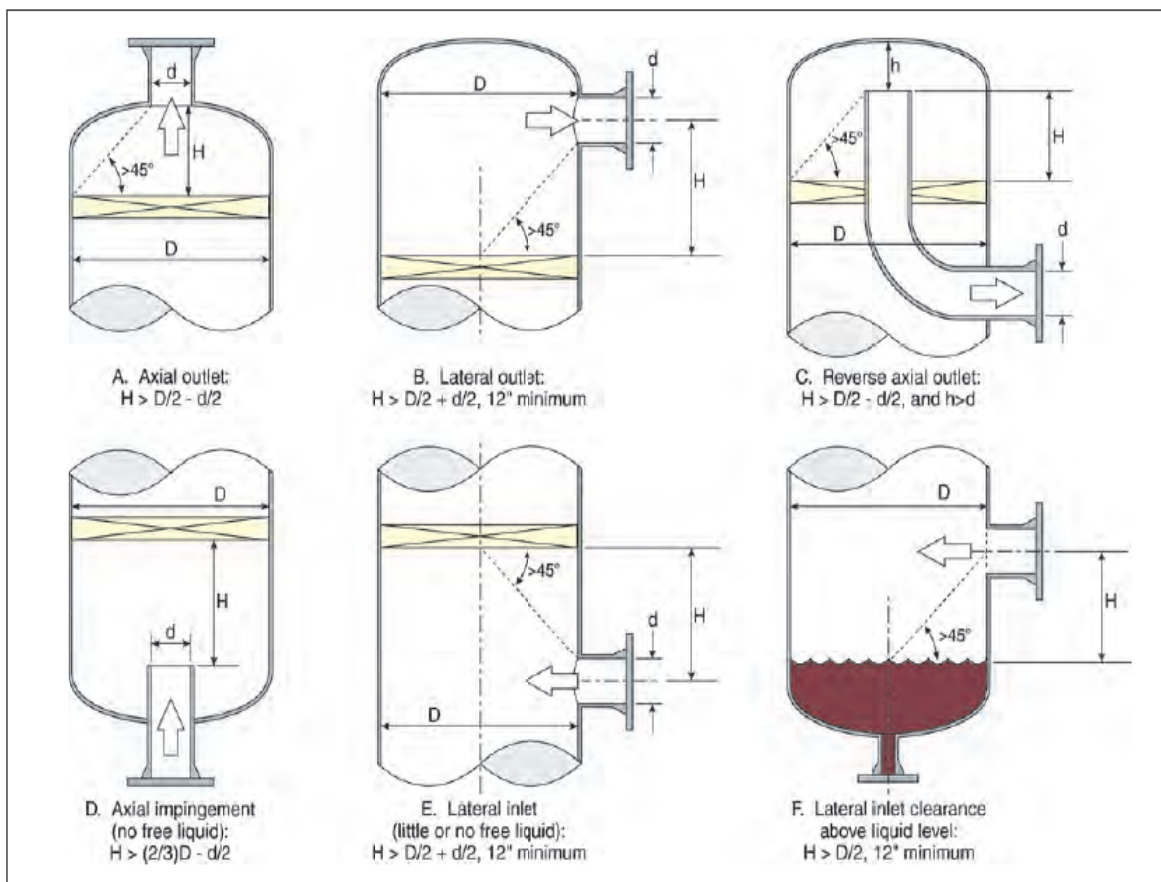
(Note 4) Minimum 150 mm (6 inches)

DATE: 09 Jun 2011

(Note 5) Baffle or Flash Guide (See, SPD0022ERN-USA, Tower, Section 5.3.1)

(Note 6) $(D - D_m) \geq 100 \text{ mm (4 inches)}$ for support ring

Fig. 3-5: Spacing guidelines to avoid entrainment in mist eliminators ⁽¹⁰⁾

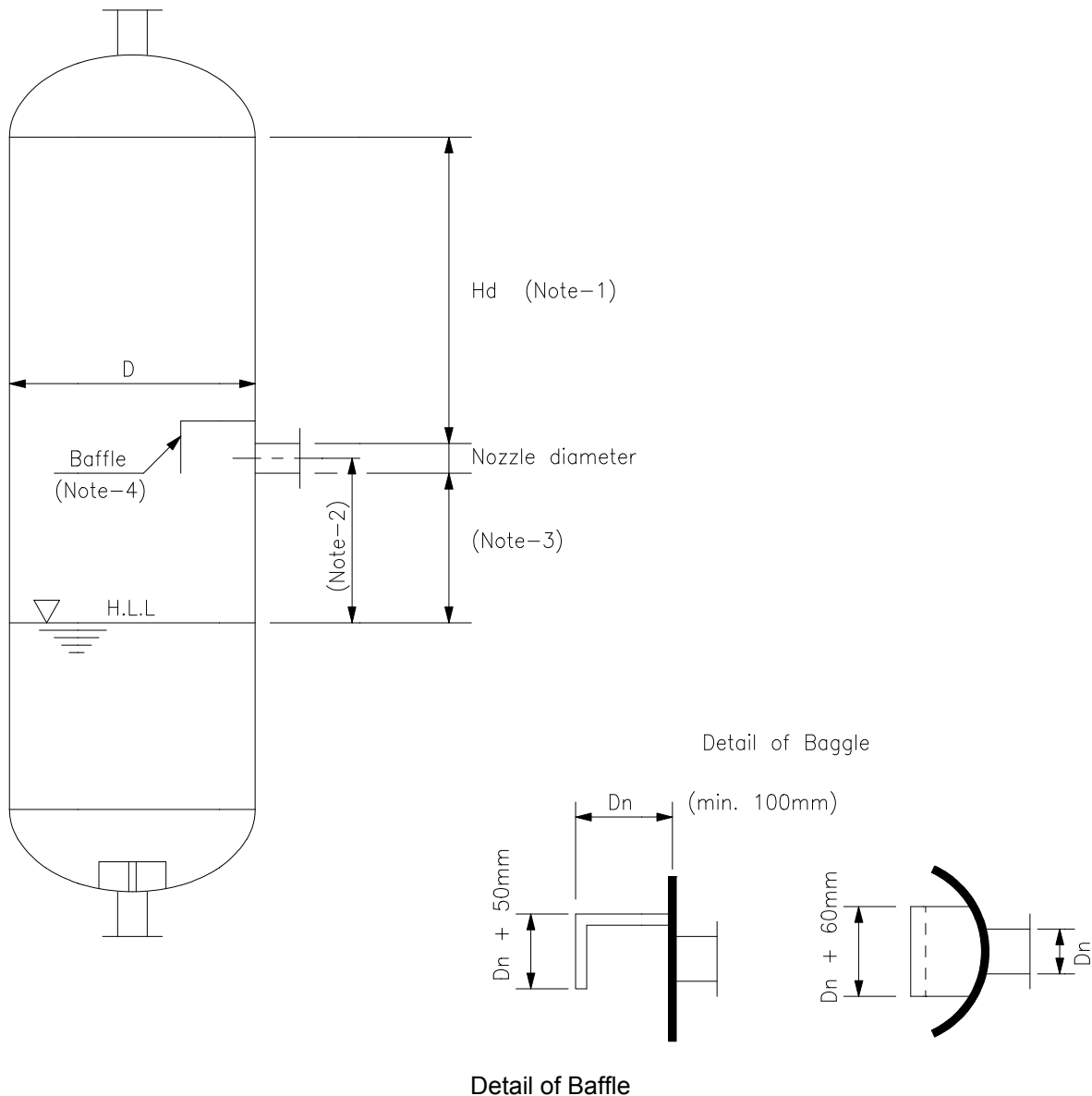


Generally accepted spacing guidelines to maintain even velocity profile and avoid entrainment in mist eliminators in cylindrical vessels with axial flow

	DESIGN MANUAL DRUM	SPD0023ERN-USA
DATE: 09 Jun 2011		REV.: 2 Page 32 of 38

Fig. 3-6: Vertical Vessel without Wire Mesh Pad

Wire mesh pad need not be provided where K ($K = U \sqrt{\rho_v / (\rho_L - \rho_v)}$) is below 0.1 ft/sec.



(Note 1) Of the following, the largest value shall be used:

$H_d \geq 18" + H_v$ (H_v ; from Fig. 3-3)

$H_d \geq 24"$

 SAMSUNG ENGINEERING	DESIGN MANUAL DRUM	SPD0023ERN-USA REV.: 2 Page 33 of 38
DATE: 09 Jun 2011		

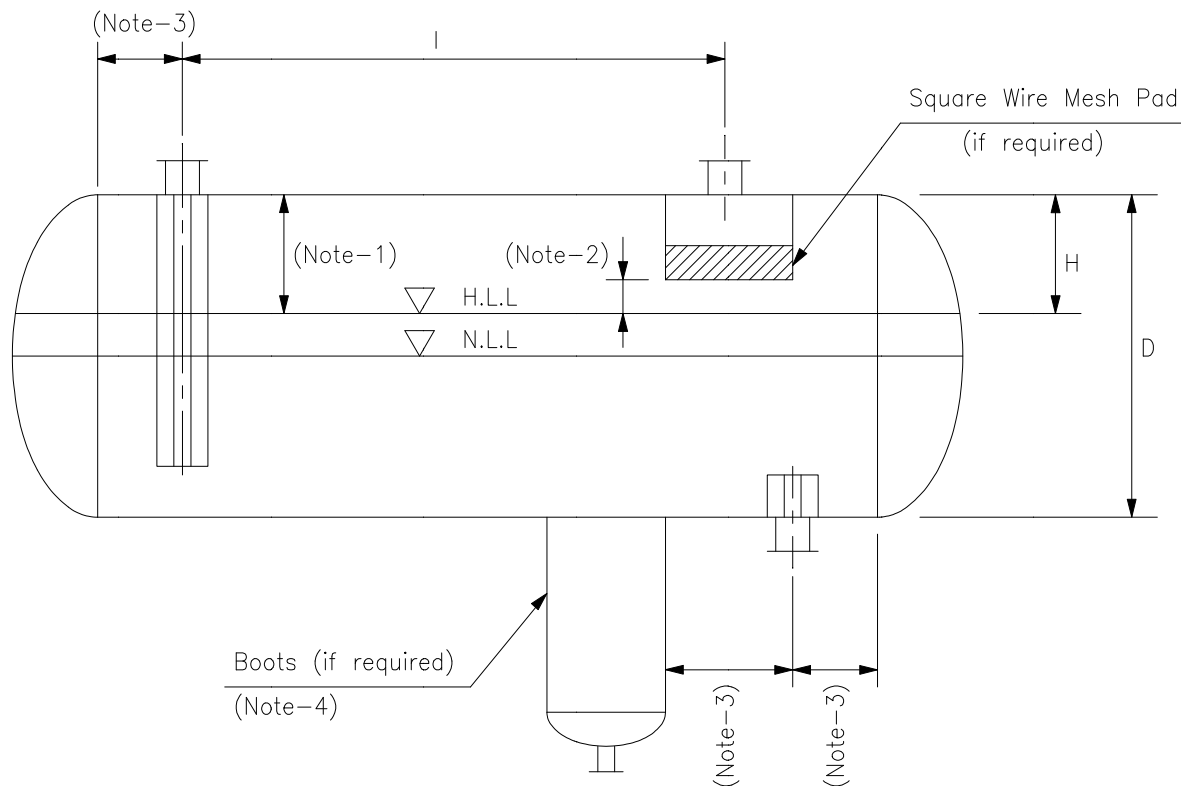
$H_d \geq 0.25D$ (D = Drum diameter, inches)

(Note 2) Minimum 300 mm (12 inches)

(Note 3) Minimum 150 mm (6 inches)

(Note 4) Baffle or Flash Guide (See SPD0022ERN-USA, Tower, Section 5.3.1)

Fig. 3-7: Horizontal Separator



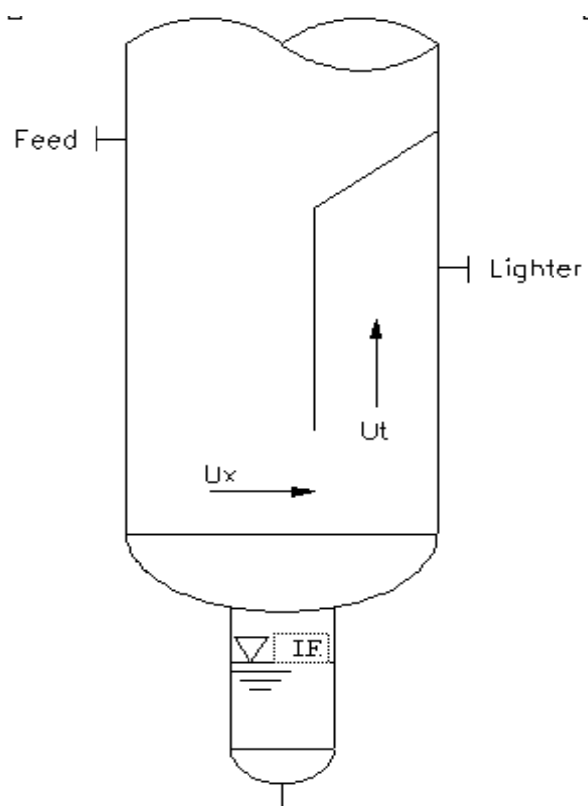
(Note 1) 20% of drum diameter or 300 mm (12 inches), whichever is the greater.

(Note 2) Minimum 150 mm (6 inches)

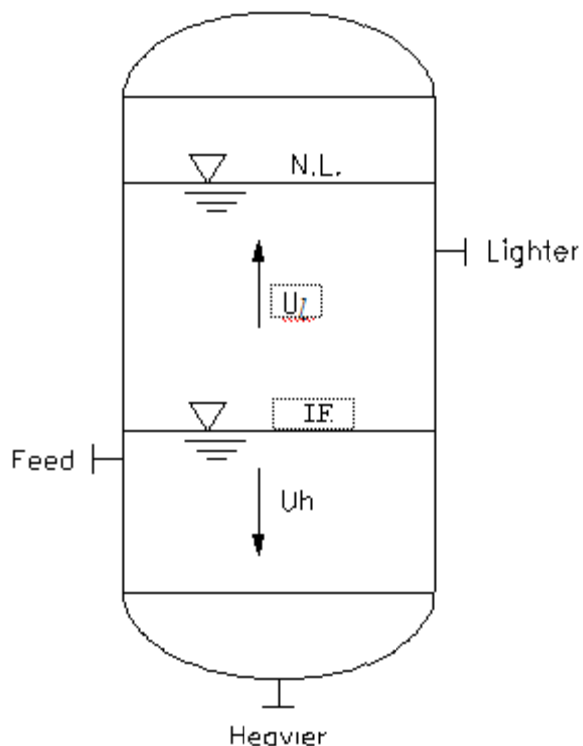
(Note 3) Minimum

(Note 4) See Section 3.2.3 (4)

Fig. 3-8: Vertical Liquid-Liquid Separator



U_x is assumed to be equal to terminal velocity U_t , i.e.,
 $U_x = U_t$



U_h or U_L , whichever is the larger, is made equal to the terminal velocity U_t

Fig. 3-9: Horizontal Liquid-Liquid Separator

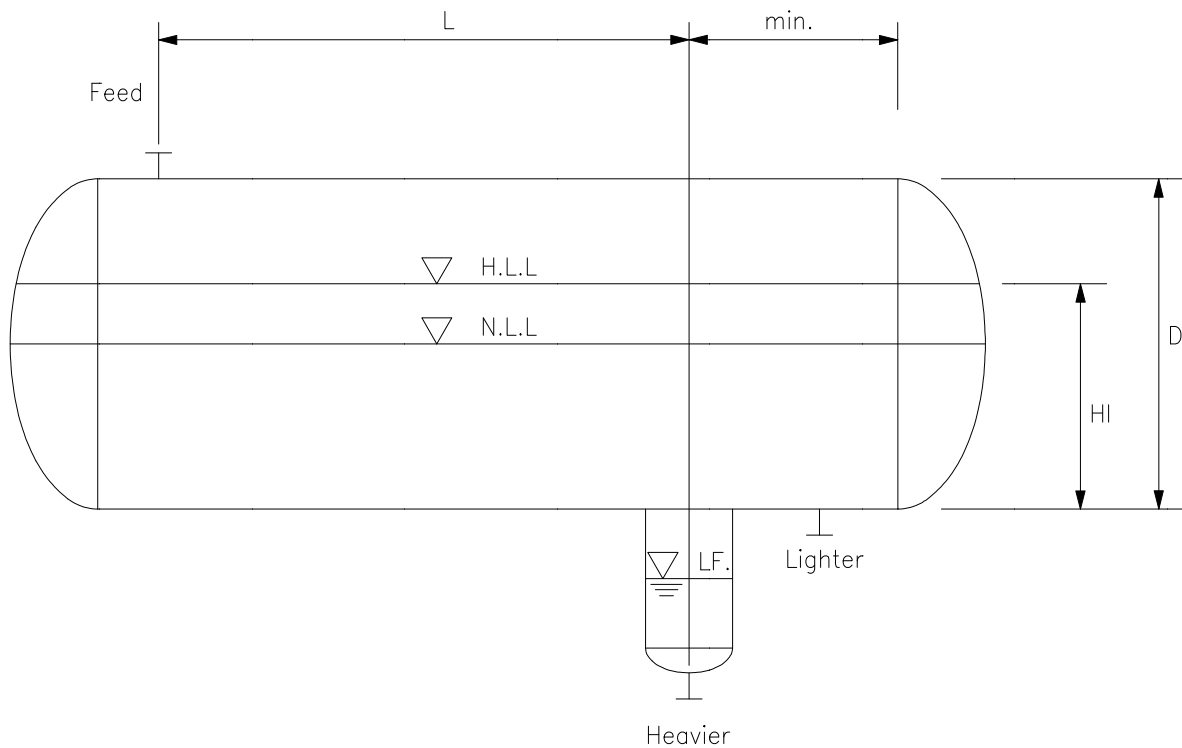
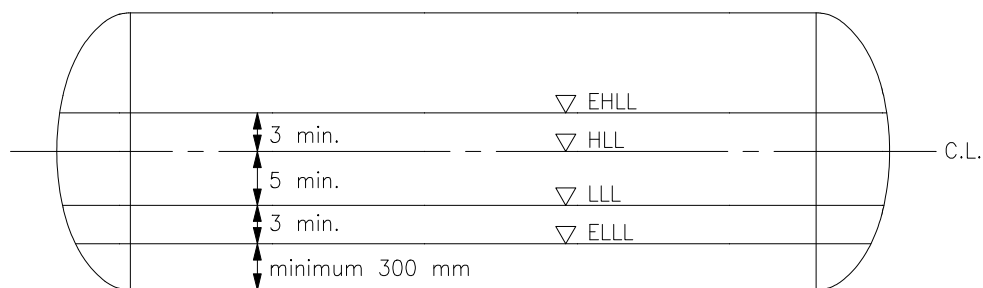


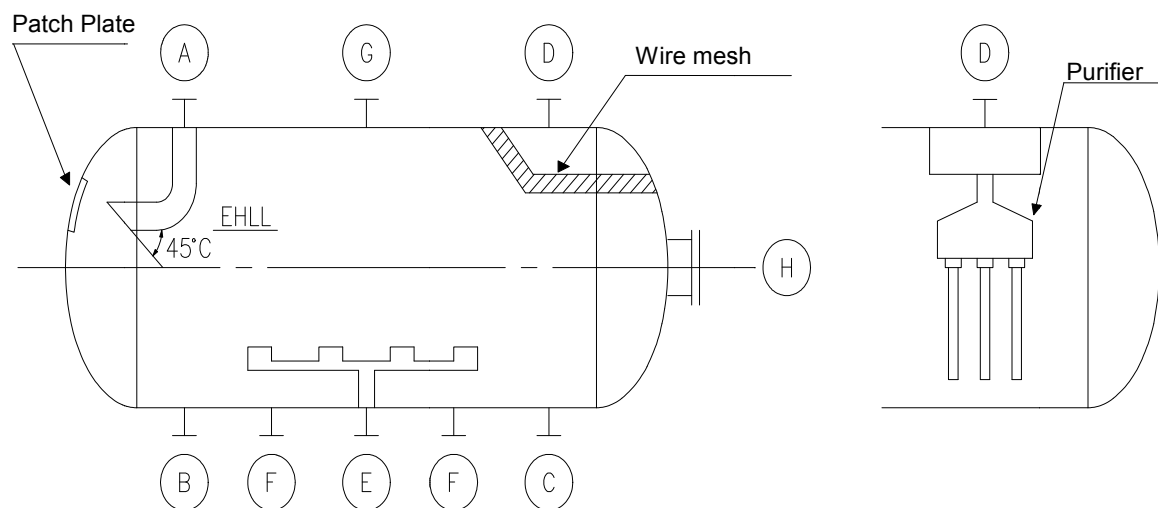
Fig. 3-10: Steam Drum

(a) Holding Time



DATE: 09 Jun 2011

(b) Typical Layout



- (A) Steam/water inlet
- (B) Fresh water inlet
- (C) Circulation water outlet
- (D) Steam Outlet

- (E) Continuous blow down
- (F) Intermittent blow down
- (G) S.V nozzle
- (H) Manhole

(c) Multi-Nozzle

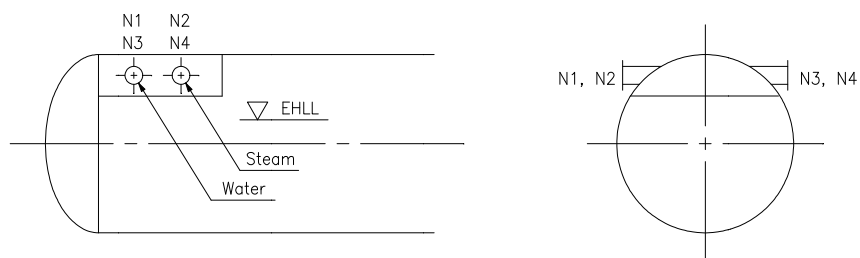
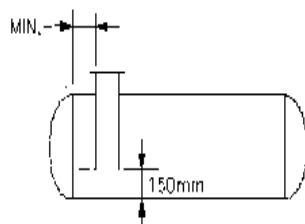
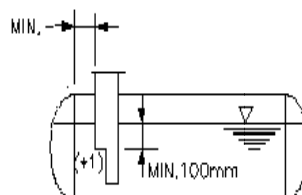


Fig. 3-11: Distributor and Baffle

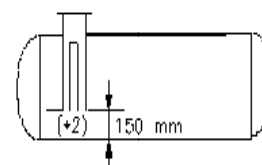
All Liquid (one liquid phase)



All Liquid (two liquid phase)



Vapor Liquid Mixture



Note :

- (*) The open area should be equal to the cross-sectional area of the nozzle or larger
- (+2) The slit area on two sides should be equal to the cross-sectional area of the nozzle or larger
- (+3) The notch should be made along the pipe center line.
- (+4) Baffle

