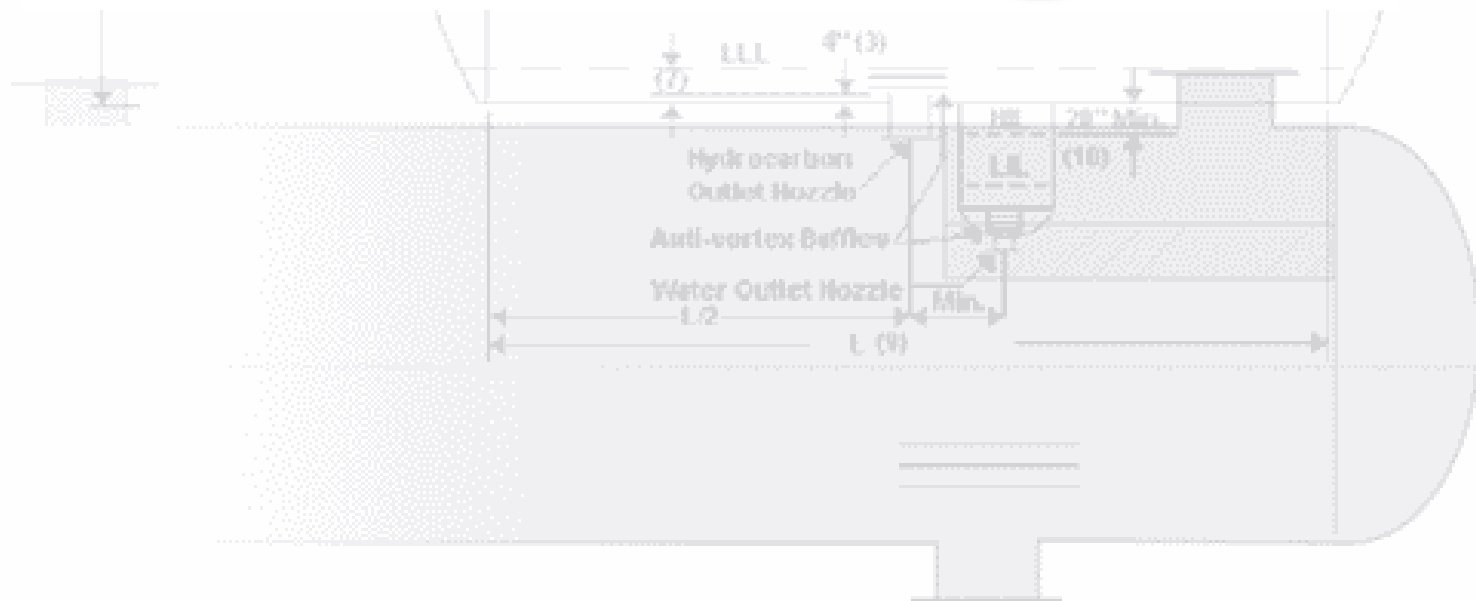


PROCESS DESIGN METHODS COURSE

Drum Design



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Importance of Separator Drum Design

- Separator drums are used throughout a plant, wherever physical separation is required. Separator drum services include:
 - Distillate reflux drums
 - Steam drums
 - Water disengaging drums
 - Blowdown drums
 - Flare drums
 - Feed surge drums
- Drum design parameters are also applied when rating existing separators. In addition, some of the drum design criteria may be applied to other process equipment in the plant.
- Drum design draws on large ExxonMobil experience knowledge base
- Drums may separate using gravity or other means (electrical charge, etc.)



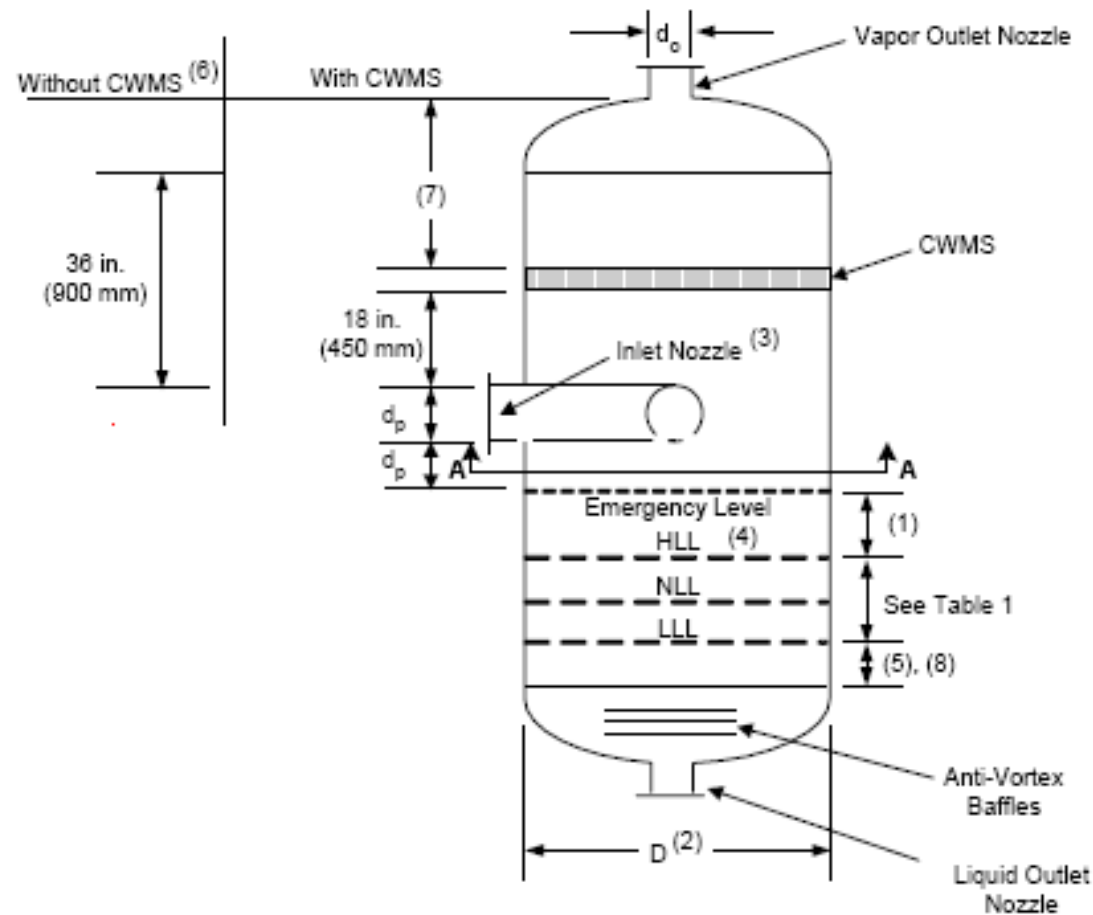
Principles of Gravity Separation

- Physical separation of:
 - Vapors from liquids
 - Immiscible liquids into light and heavy phases
- Gravity separation utilizes density difference between phases.
- Minimize velocity and momentum to improve separation efficiency
- General types of separators:
 - Vapor - Liquid
 - Liquid - Liquid
 - Liquid - Liquid - Vapor
- Vessels are typically designed to accomplish one or more of the following:
 - De-entrain liquid or prevent liquid entrainment
 - Settle water/hydrocarbons
 - Provide surge capacity

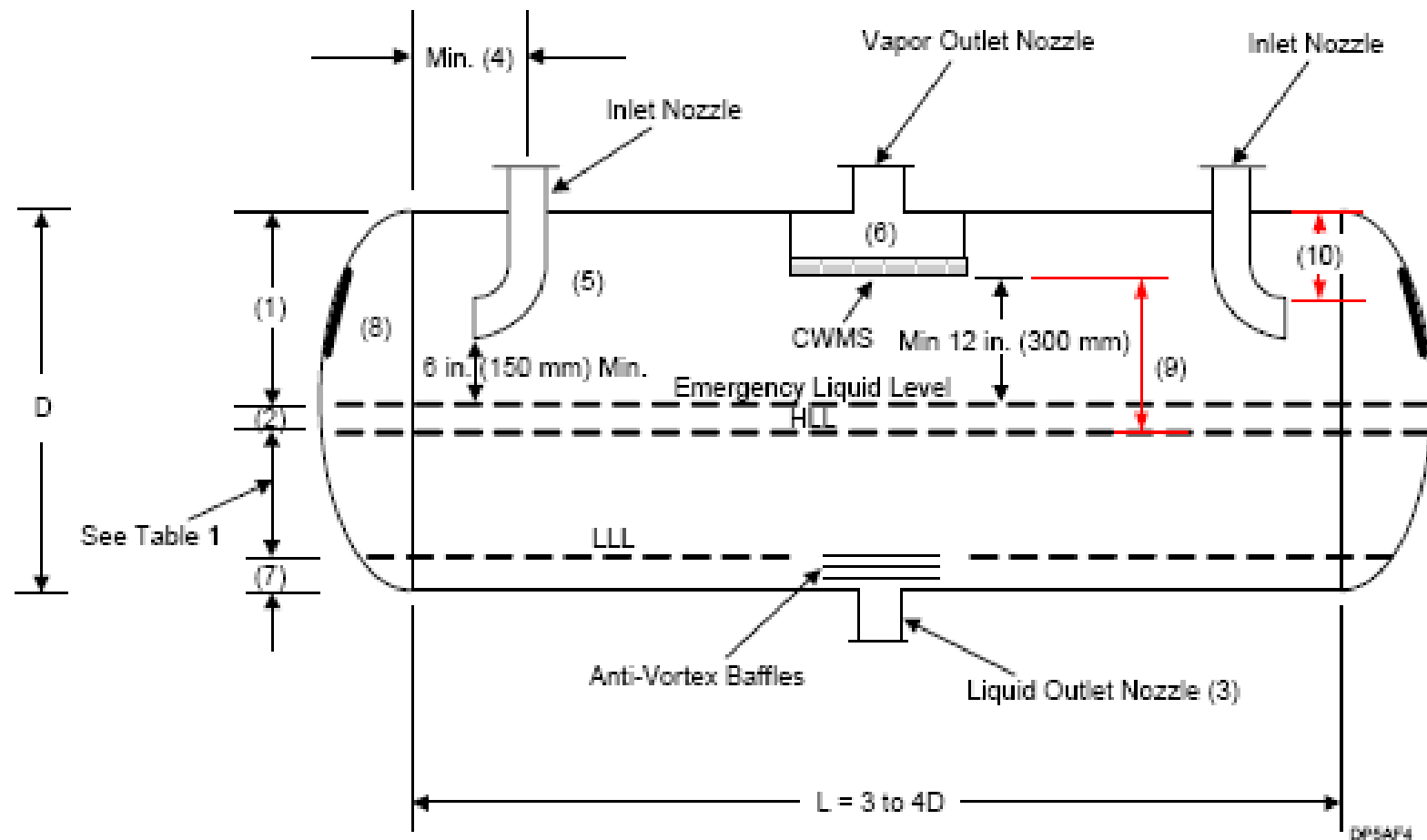
Vapor – Liquid Separation

- Phase separation is one of the most common process steps in processing plants. Of the five types of phase separation (vapor-liquid, liquid-liquid, vapor-liquid-liquid, vapor-solid and liquid-solid), vapor-liquid separation is the most commonly encountered in chemical plants.
- Many of our processes involve vapor-liquid contacting or condensation of vapor.
- Distillation (fractionation), often used for product purification, involves liquid-vapor separation within the tower and again in the tower overhead system.
- Vapor-liquid separation occurs in a number of other applications in addition to condensation and distillation, including:
 - Cooled compressor discharges
 - Instrument air systems
 - Steam generation
 - Fuel gas systems

Typical Vapor – Liquid Separator Drum



Typical Vapor – Liquid Separator Drum

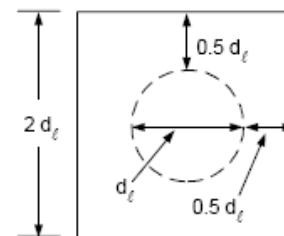
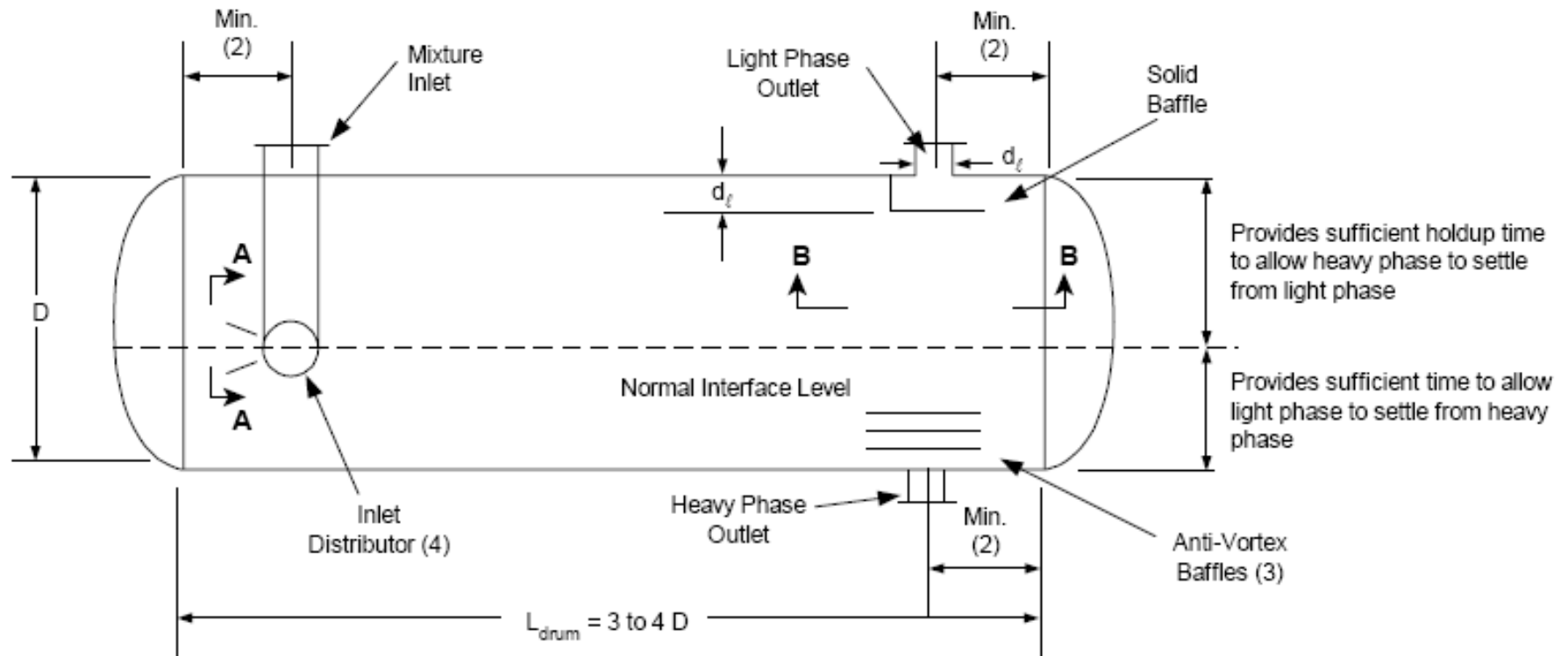


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Liquid – Liquid Separation

- Immiscible liquids can be separated via gravity settling
 - Oil and water
 - Light and heavy oil
- Settling of each liquid phase within the other
- Must be aware of potential to form stable emulsions within the system
 - Settling becomes extremely difficult
 - Special criteria listed in DP V-B
- Gravity separators will not remove enough free water to meet distillate product quality specifications
 - Cannot achieve less than 200 ppm free water in hydrocarbon phase
 - Use sand filters, salt dryers, etc. to meet product quality needs

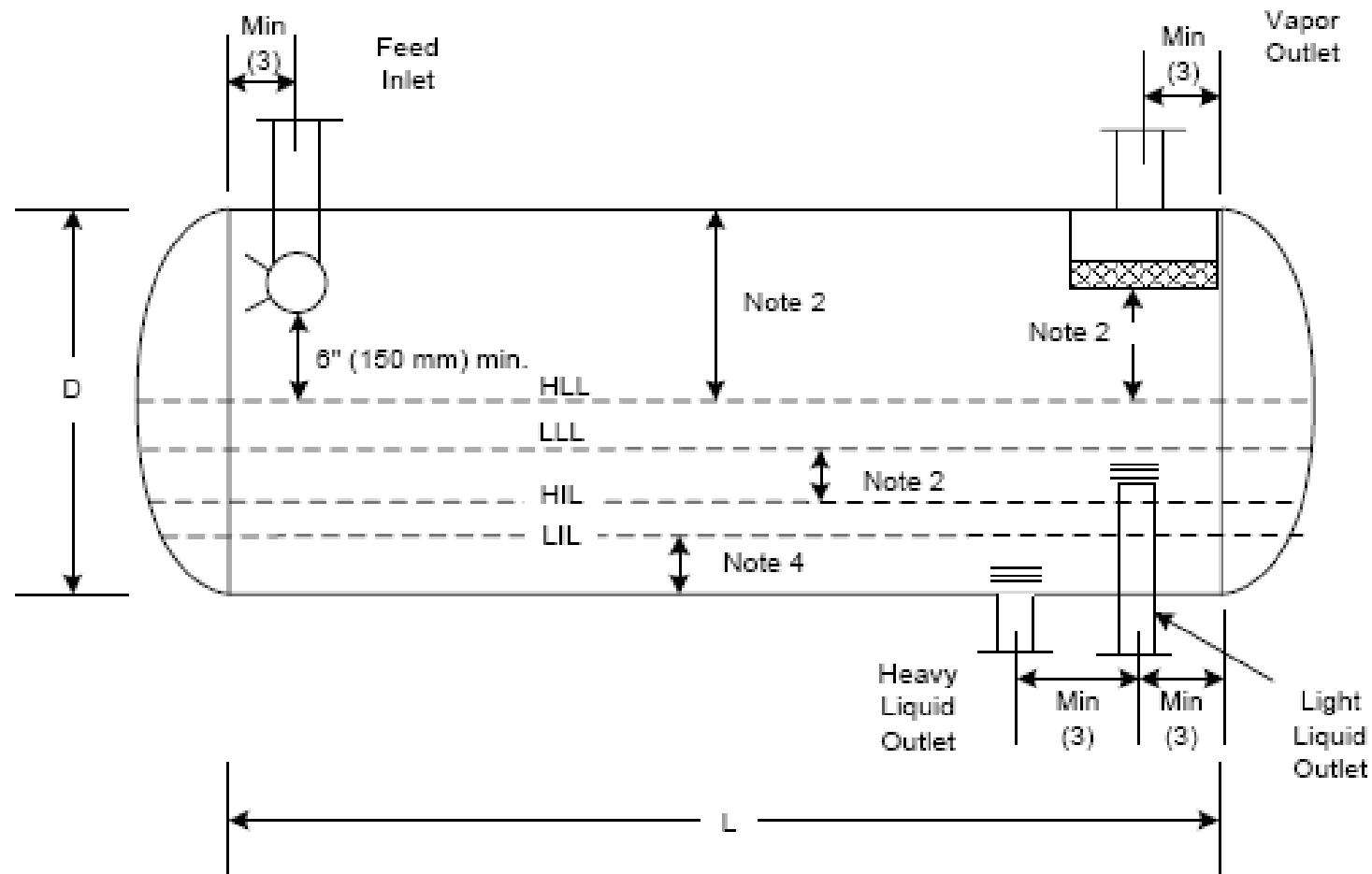
Typical Liquid – Liquid Settling Drum



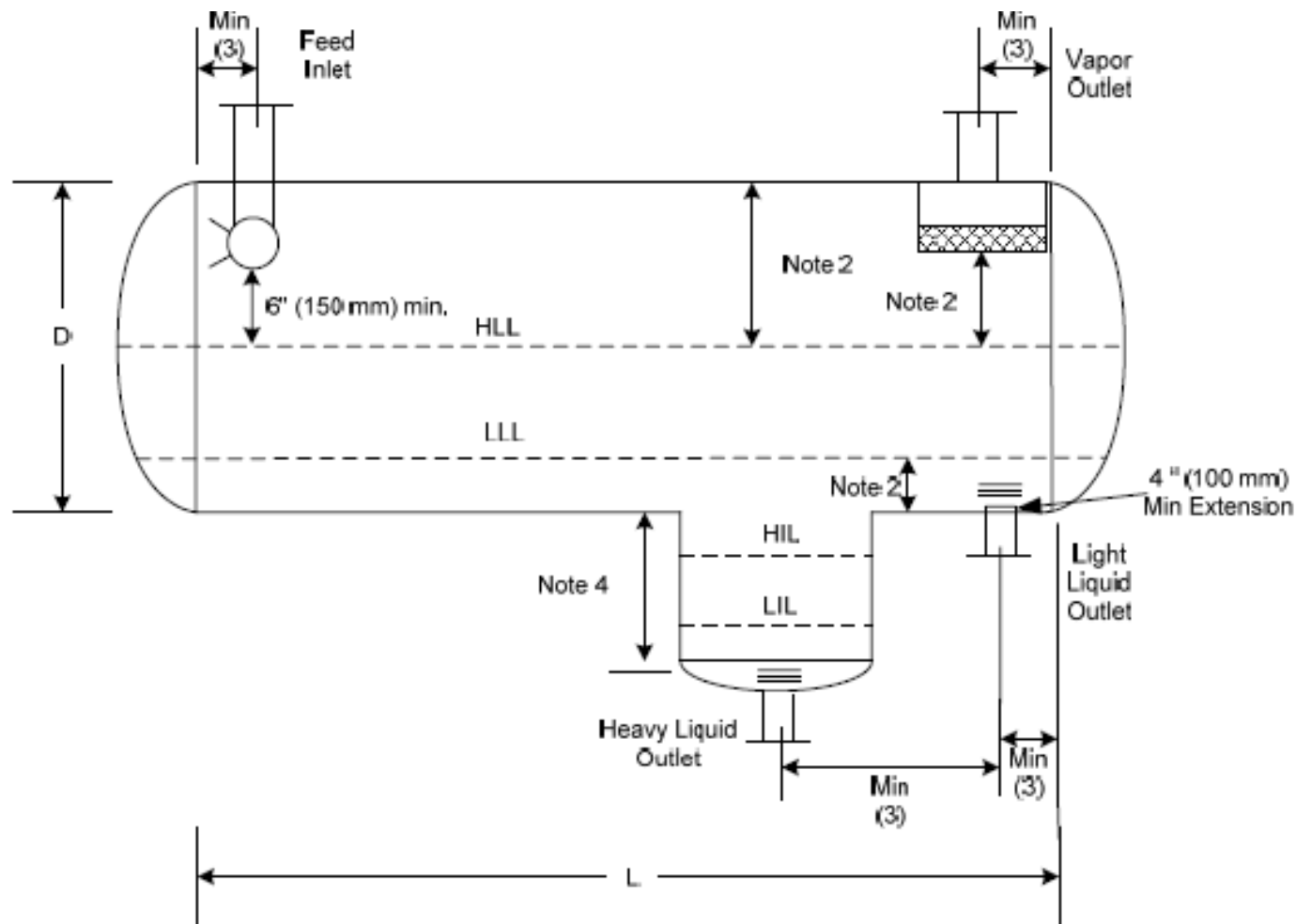
Vapor – Liquid – Liquid Separation

- Immiscible liquids can be separated via gravity settling
 - Oil and water
 - Light and heavy oil
- Settling of each liquid phase based on
 - Each phase dispersed in the other
 - Holdup time of bulk phase $\geq$ time for drops to reach interface
- Separating velocity calculated using appropriate law and assumed droplet size
 - Maximum droplet separation velocity: 10 in / minute (250 mm / min)
- Use settling pot for small amounts of heavy phase
- Special considerations for amine and sour water service
 - Uses an internal box for separation

Typical Three Phase Separator



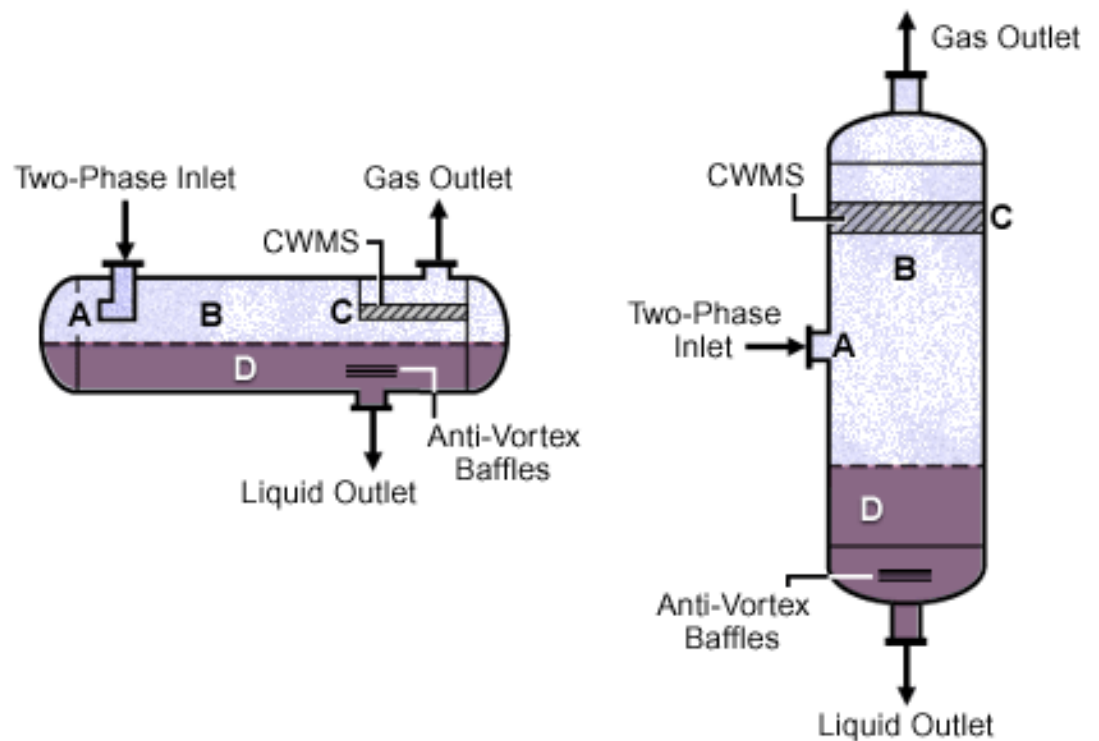
Typical Three Phase Separator w/ Settling Pot



Stages of Separation Within a Separator Drum

Vapor-liquid separators have four distinct sections, in which various stages of separation may occur. Separator drums are designed to optimize each type of separation.

- A = Primary Separation
- B = Gravity Settling
- C = Coalescing
- D = Liquid Collecting



Separator Drum Design Considerations

- The first step in designing or checking the design of any separator is to determine the rates and physical properties (density, viscosity and liquid surface tension) of the phases be separated.
- A number of design considerations must be evaluated when designing a new separator or rating an existing drum.
- DP V-A and V-B provides specific criteria for special services
 - Compressor knock-out drums
 - Fuel gas knock-out drums
 - Crude flash drum
 - HP separators
- Blowdown drums and others used for environmental or safety purposes are covered in other DPs



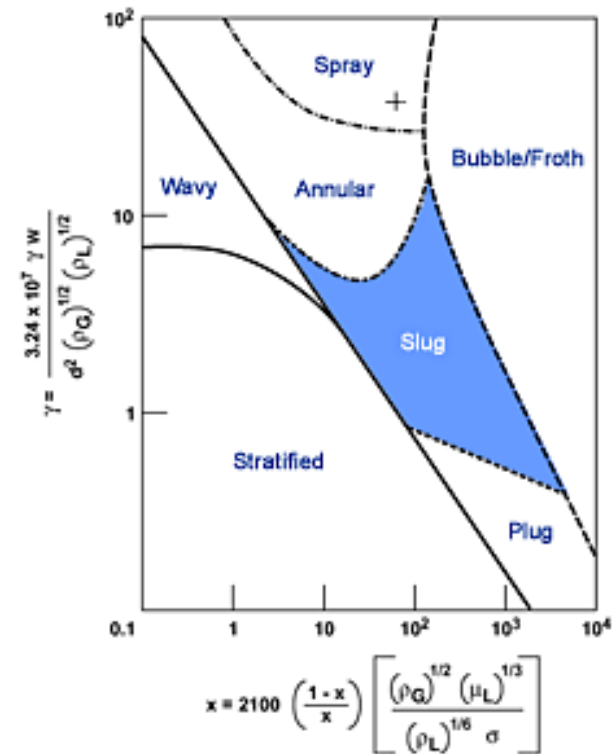
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Drum Orientation

- Vertical drums are generally used when
 - Plot space is limited
 - Low liquid loading
- Horizontal drums are generally used when
 - The volume of vapor and / or liquid is great
 - Liquid – liquid or vapor – liquid – liquid separation
 - Space is not an issue
 - The flow in the inlet piping is slug or bubble flow

Flow Regime in the Inlet Piping / Nozzle Sizing

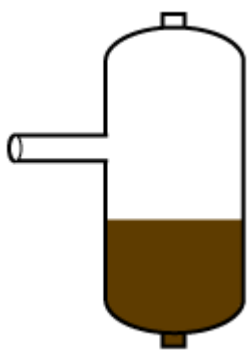
- The flow regime and the inlet velocity affects droplet size, which affects separation efficiency. Creating droplets that are too small makes separation more difficult. Altering the diameter of the inlet line can alter flow regime.
 - Typically design for annular/spray flow
 - Reduces inlet piping diameter
 - Increasing vapor velocity increases liquid carryover
 - Designing for stratified/wavy flow
 - Increases separation efficiency
 - Increases inlet pipe diameter
 - Slug/bubble flow
 - Causes excessive liquid carryover and pipe vibration
- Inlet nozzles are typically line size
 - Check Table 1 in DP XIV-B
 - Generally use a maximum pressure drop of 0.4 psi / 100 ft (0.09 kg/cm² / 100 m)



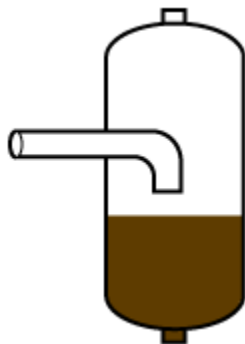
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Feed Distributor / Inlet Momentum

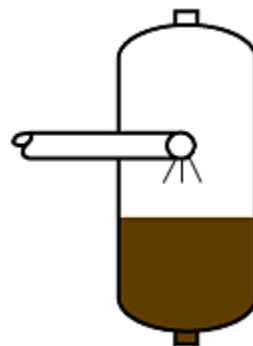
- Inlet nozzle / distributor is the first place separation occurs in the drum
 - Design is critical to ensure bulk separation occurs
 - Poor design can create excessive entrainment
 - Low velocity / pressure drop provides time for disengaging
- Different drum services required different types of nozzle inlets. See DP V-A.
- Inlet momentum must be checked for good liquid – vapor distribution
 - Typical limit is 2025 lb/ft-sec² for vertical drums (3040 kg/m-sec²)
- 4 main types of distributors are



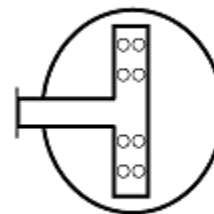
**flush inlet,
open nozzle**



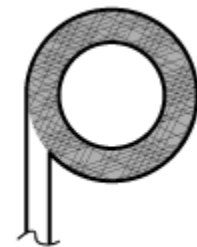
elbow



**slotted or holed
distributor**



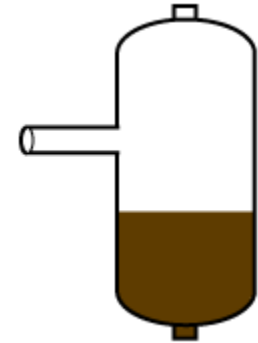
tangential



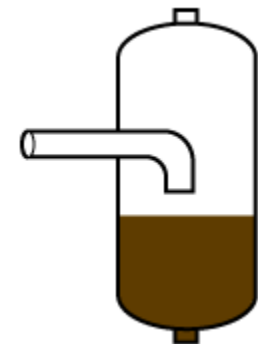
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Flush Inlet and Elbow Distributors

- Flush inlets not recommended for new designs
 - Poor separation caused by feed shooting across drum
 - High liquid re-entrainment rate
- 90° elbow inlet is first upgrade above a flush nozzle
 - Directs feed toward the drum head (horizontal drum)
 - Lower liquid re-entrainment rate than flush inlet
 - Higher rate than slotted distributor
 - Not recommended for vertical drums (see drawing)
 - Acceptable choice for general vapor – liquid separation
 - Check Table 3 in DP V-A for applicability
 - Cheaper / easier to fabricate than slotted distributors



**flush inlet,
open nozzle**

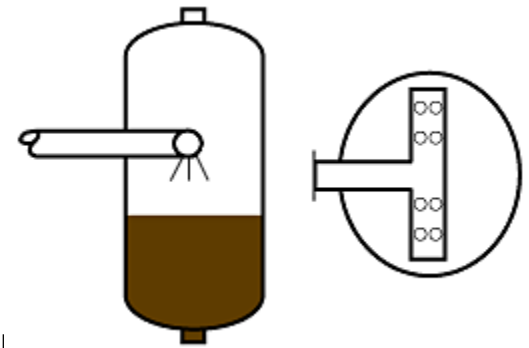


elbow

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Slotted / Holed Distributors

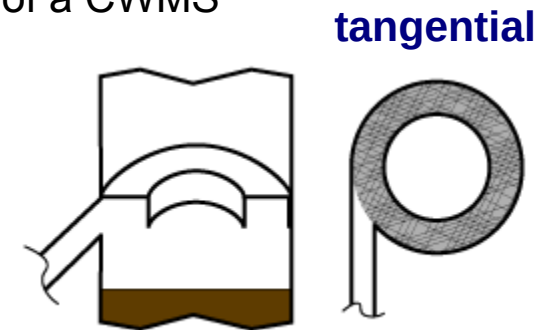
- Slotted / holed inlet distributor improves over inlet elbow performance
 - Directs feed toward the drum heads / walls
 - Low liquid re-entrainment rate
 - Acceptable choice for general and specialty services
 - Check Table 3 in DP V-A for applicability
- Pressure drop / velocity through the distributor is critical
 - Maximum pressure drop of 0.5 psi (0.035 kg/cm²) through
- Other design criteria include
 - Slot open area $\geq$ inlet nozzle cross-sectional area
 - Minimum slot width or hole diameter of 1/2" (13 mm) to prevent plugging
 - Discharge angle based on drum orientation
- Additional design criteria listed in DP V-A
 - Fouling service



**slotted or holed
distributor**

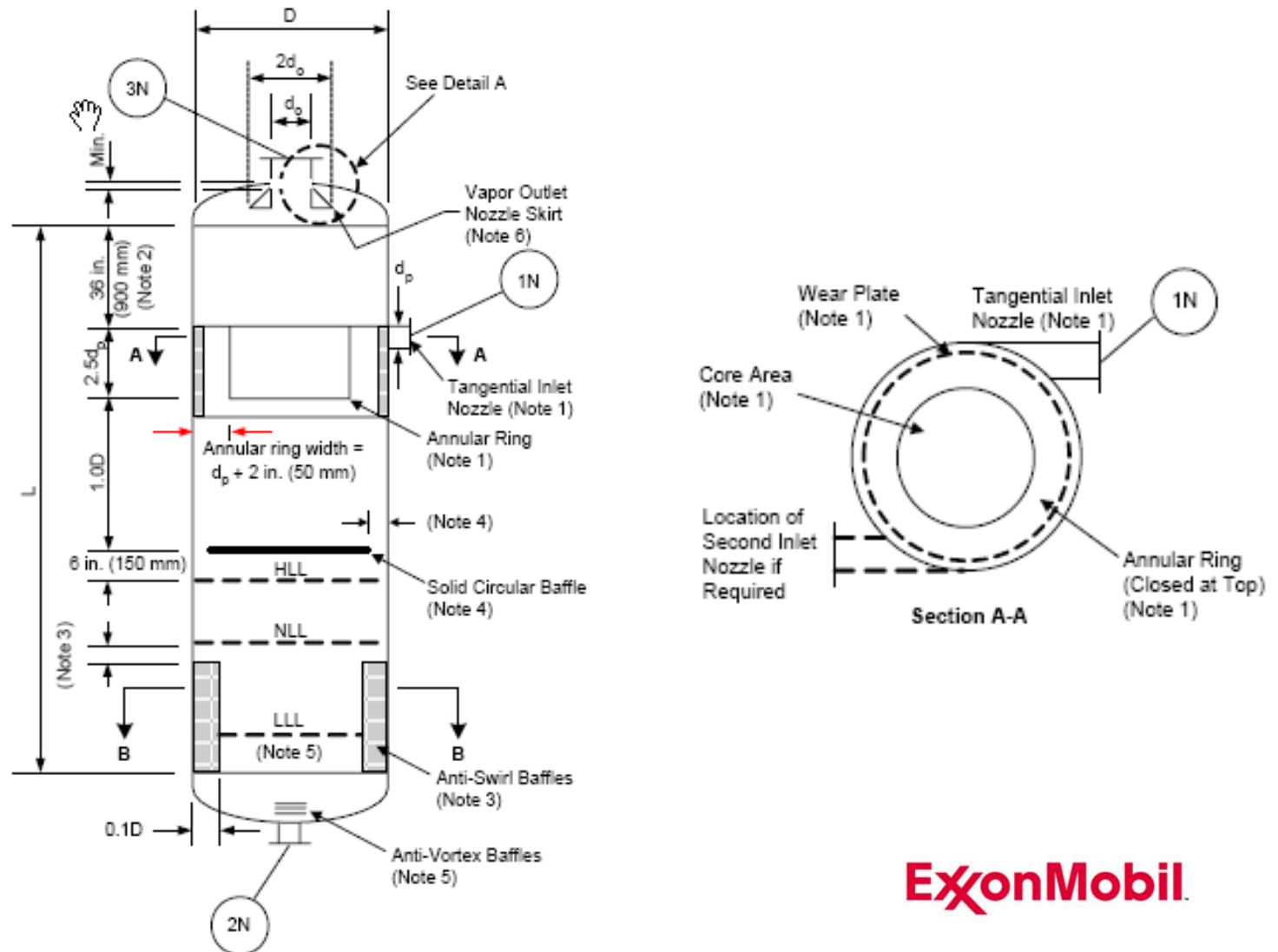
Tangential Inlets

- Special inlet type used for limited services
 - Fuel gas: corrosive / fouling, central collection drum
 - Slug flow regime present in the inlet piping (crude flash drum)
 - Non-condensable blowdown drums
 - Solids separation
- Feed enters off-center and rotates around an annular ring
 - Forces liquid to walls of drum
 - Vapor is able to make the turn up to the vapor space
- Allows for good liquid / vapor separation without the use of a CWMS
- Design criteria / dimensions are available in DP V-A
 - Up to 200% of critical velocity allowed
 - Consult with EMRE Specialist for final design



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Typical Tangential Inlet Arrangement



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Problem – Inlet Nozzles

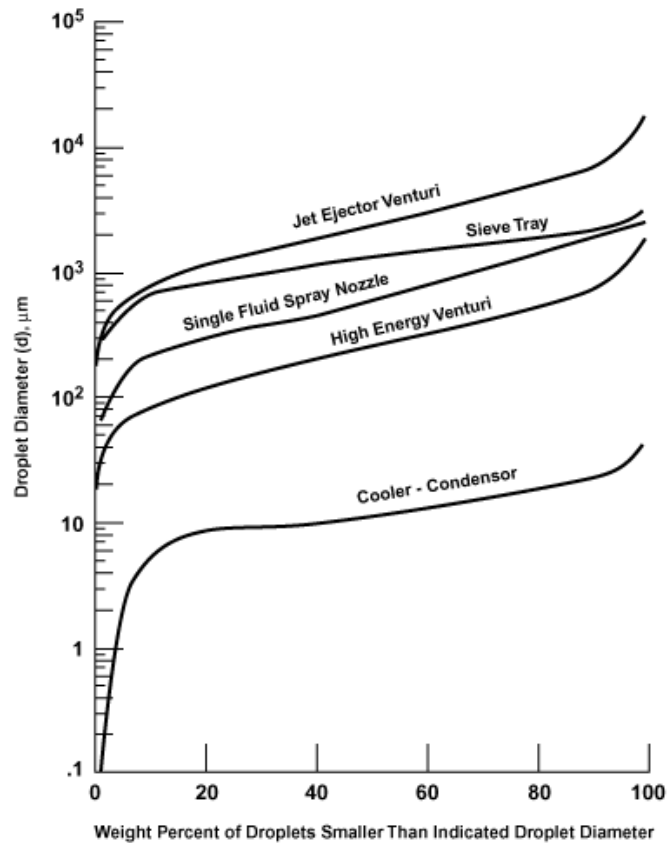
- When would you use a flush nozzle?
- Which nozzle use for 3-phase separation?
- What is the advantage of tangential nozzle?
- Why would you use a 90° elbow instead of a slotted distributor?
- Which has more capacity, a holed or slotted distributor?
- Which is lower cost, a holed or slotted distributor?

Inlet Flow and Separation Efficiency

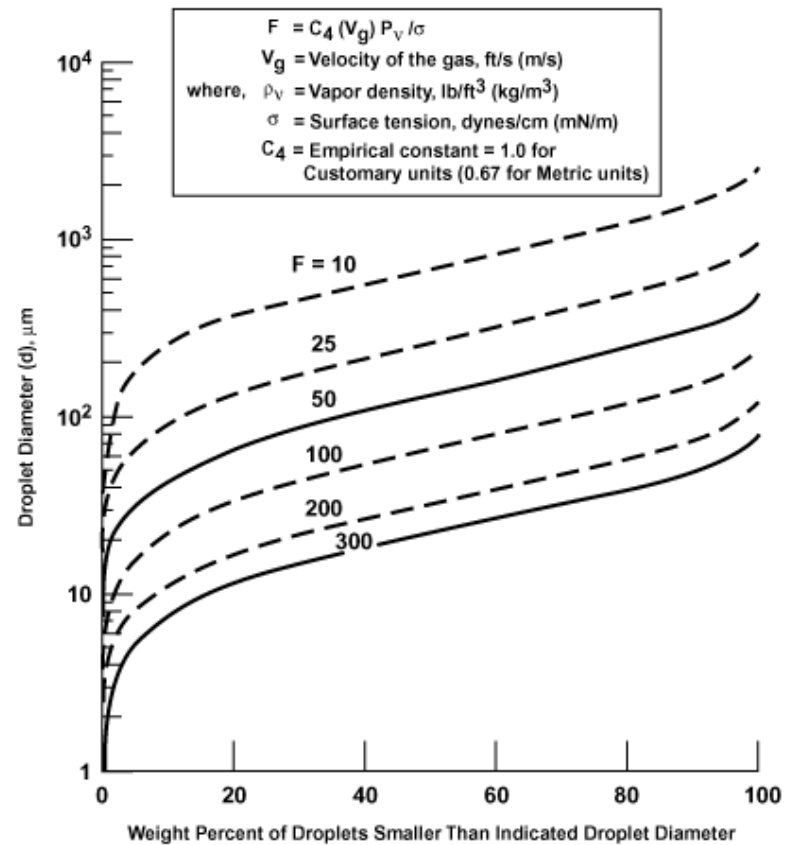
- The droplet size in a two-phase stream is determined by the source of the stream, its physical properties, and inlet line velocity. The type of equipment downstream of the separator determines the tolerance for separation efficiency (the fraction of liquid in the inlet stream that is removed from the vapor).
- Droplet size distribution and gravity settling determine the separation efficiency. If 5% of the droplets in the inlet stream are less than 200 μ and you design for 95% separation efficiency, you must remove all droplets greater than 200 μ in size.
- As the separation velocity equations show, acceptable droplet size determines the acceptable velocity. Droplet size is a function of the origin:
 - Condensation processes (fog) produce very small droplets.
 - Liquid-vapor mixing systems such as spray nozzles produce much larger droplets.
 - Two phase flow in pipe can produce a wide range of droplets.

Droplet Size

Estimates Drum Inlet Drop Size Distribution Formed by Various Mechanisms



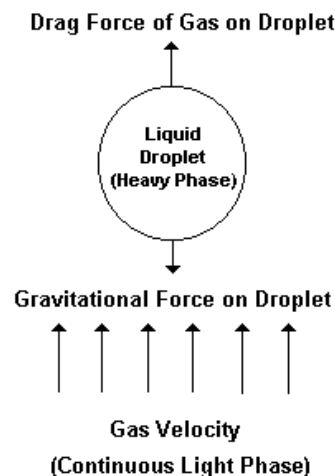
Estimates Drum Inlet Drop Size Distribution for Drops Formed by Shear Forces in Piping



Note: The droplet forming mechanism is an input into EMOdrum

Separation Velocity

- Vapor velocity, the relative density of liquid and vapor, and liquid droplet particle size are key factors in determining separation or settling rates. There are three basic equations for determining separation velocity.
- The three basic equations-Stokes' Law, Intermediate Law, and Newton's Law - represent a force balance between gravity on the liquid droplets and the buoyancy or drag of the rising vapor for different flow systems as distinguished by the Reynolds Number for the system. For any droplet size there is a vapor velocity that would lift the droplet.



Critical Vapor Velocity

- For vapor/liquid separations, the key parameter is the critical vapor velocity, V_c
 - empirically derived
 - not related to sonic velocity
 - not a step change in entrainment above V_c
- Ensures that the vapor velocity through the separator drum is sufficiently low to prevent excessive liquid carryover.
- Critical velocity is defined by the equation below, which is found in ExxonMobil Design Practices Section V-A.

$$V_c = C_1 \left(\frac{\rho_L - \rho_G}{\rho_G} \right)^{0.5}$$

where: V_c = Critical velocity, ft/s (m/s)
 C_1 = Empirical constant = 0.157 ft/s (0.048 m/s)
 ρ_L = Liquid density at conditions, lb/ft³ (kg/m³)
 ρ_G = Vapor density at conditions, lb/ft³ (kg/m³)

Vapor Space

- Minimum vapor space requirement is based on providing enough space for liquid droplets to disengage from the vapor
 - Changes with droplet size and separation efficiency
- Minimum vapor space can be represented as a percentage of critical vapor velocity
 - Typically limited to 100% V_C for general service
 - Higher V_C allowed with the use of a CWMS
 - Removes liquid droplets that are still entrained in the vapor
 - Can go to 125% V_C for general services

Vapor Space – DP V-A Table 1 Example

- Table 1 in DP V-A lists acceptable V_C for various services with and without CWMS
 - Some specialized services are not covered in the DPs:
 - DP XV-D states design criteria for blowdown drums and flare KO drums
 - EMRE Technical Report EE.43E.99 provides revised and more extensive design criteria for debottleneck projects
 - If you have an application where you believe it is possible to deviate from the DP criteria, contact an EMRE separation specialist.

Table 1
Typical Design Criteria for Various Services

DESIGN PARAMETER	FEED SEPARATOR DRUMS FOR AMINE SCRUBBERS	HIGH-PRESSURE SEPARATORS	HORIZONTAL CRUDE FLASH DRUM	VERTICAL CRUDE FLASH DRUM
Normal Drum Position	Vertical	Horizontal or Vertical ⁽⁴⁾	Horizontal	Vertical
Allowable Vapor Velocity, % of V_C				
+ Without CWMS	Not Allowed	100 ⁽⁵⁾	40(drum), 180(chevron)	40(drum & chevron)
+ With CWMS ⁽¹⁾	100 ⁽²⁾	100-125 ⁽²⁾	40(drum), 100(CWMS)	40(drum & CWMS)

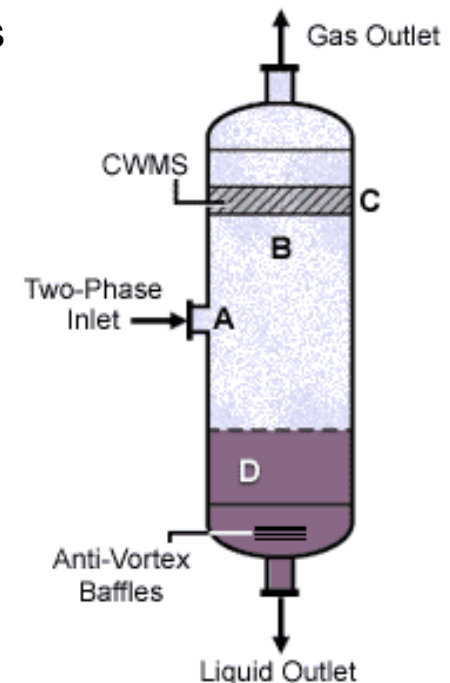
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Liquid Re-Entrainment at Liquid Surface

- Liquid already collected in the drum can be re-entrained / swept from the liquid surface and carried overhead
- Rate is dependent on many factors including:
 - Gas velocity at the inlet nozzle (function of nozzle size)
 - Inlet nozzle type (flush, 90° elbow, slotted)
 - Distance from the inlet nozzle to the liquid level / impinging surface
 - Physical properties of the fluid (surface tension, densities, and viscosities of liquid and gas phases)
 - Operating pressure
- Calculate the maximum allowable velocity to prevent re-entrainment and change the distributor type / open area as needed
 - Slotted distributors provide the most area

Enhanced Removal of Liquid from Vapor

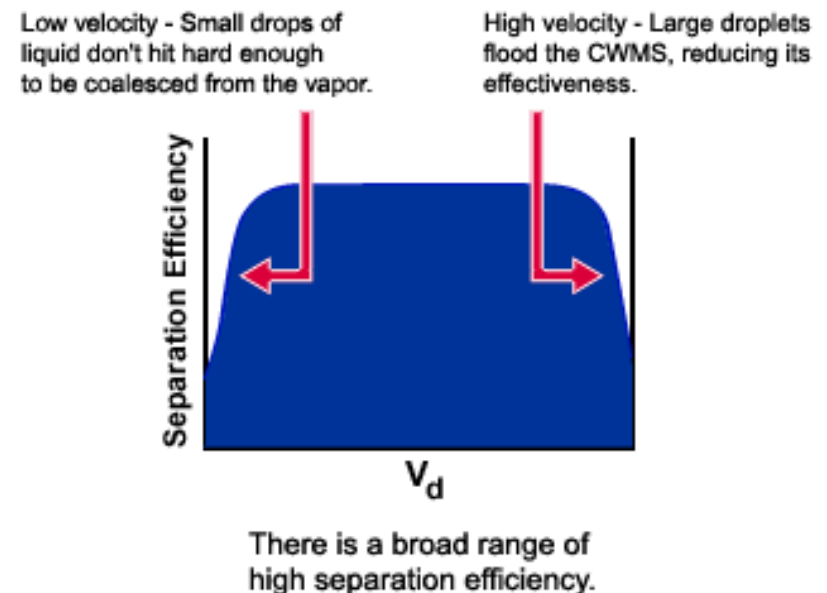
- Coalescing is one of the four stages of separation within a separator drum. Coalescers such as CWMS, corrugated baffles, and/or a combination of the two promote the gathering of small liquid droplets into larger droplets that will separate by gravity from a vapor.
- CWMS are used in a number of services. Corrugated baffles are often used when very high separation efficiency is required with a high vapor velocity in a compact space, as in high pressure steam drums.
- Coalescing elements can impact drum design in two ways:
 - Vessels can be smaller where a coalescing element is used (higher V_C allowed)
 - An existing drum can be made to handle higher rates by adding coalescing.
- Coalescing elements are required in services where liquid removal is critical
 - Compressor suction, fuel gas, etc.
 - See Table 1, DP V-A for specific services



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CWMS and Separation Efficiency

- CWMS = Crinkle Wire Mesh Screen
- Adding a CWMS can have a dramatic effect on separation efficiency:
 - Without a CWMS, a drum can achieve a separation efficiency of 95 to 99.5%.
 - Adding a CWMS can increase separation efficiency to over 99.9%.
- The CWMS achieves the increased efficiency by coalescing droplets from 2-10 μ . It is typically sized for the same percent critical velocity as the drum. CWMS separation efficiency is dependent on vapor velocity, as shown in this representative graph.
- Horizontal and vertical orientation



CWMS

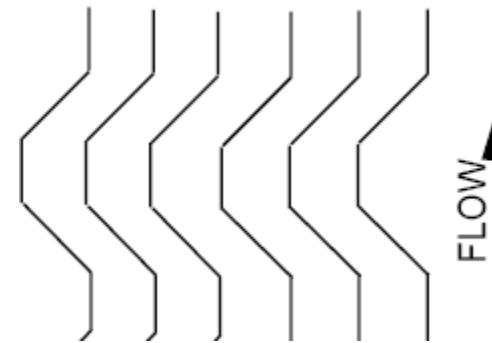


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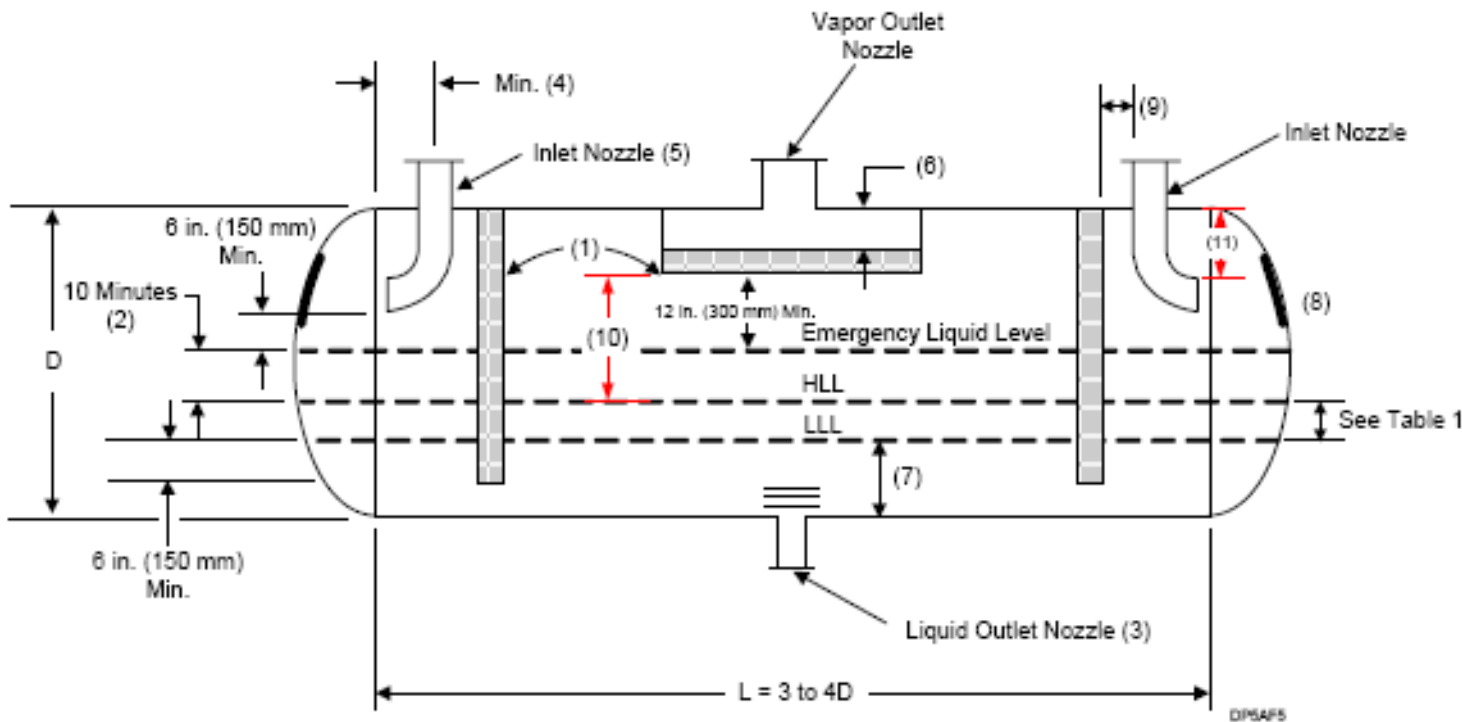
CWMS and Fouling Impacts

- In services that may plug a CWMS, consider using a vane type distributor (FLEXICHEVRON).
- Safety valve inlet must be located upstream of a CWMS in fouling service.



Horizontal and Vertical Orientation of CWMS

- Size all CWMS for the same critical velocity criteria (typically 125%)
- Provide a minimum of 6" from the bottom of the drum to the horizontal CWMS
- Locate horizontal CWMS a minimum distance away from the inlet nozzle



Liquid Holdup

- Minimum liquid hold-up is usually determined by process, control, or emergency requirements.
- The combination of liquid holdup and vapor separation determine the vessel size.
- The liquid hold-up requirement must always be considered because it:
 - may impact the volume available for vapor disengaging. Impact is much more significant for horizontal drums.
 - may affect control of downstream processes and safety considerations.

Liquid Holdup Design Considerations

- Liquid holdup requirements vary with drum service.
- Table 1 of DP V-A specifies holdup criteria for many services. However:
 - Computer applications have demonstrated that lower hold-up than given in Table 1 is possible in some services. Consult the unit applications engineer if you believe that a lower than normal holdup is desirable.
 - Sometimes drum size criteria are set by operations not covered in Table 1.
 - Criteria for furnace feed, compressor interstage and reflux drums are found in DP XII-C as well as with the plant application engineers.
 - Criteria for blowdown or flare drums are in DP XV-D.
- An Emergency Block Valve may be required in the liquid outlet line if liquid contents are toxic or vessel has large liquid inventory (Refer to DP XV-F).

DESIGN PARAMETER	FEED SEPARATOR DRUMS FOR AMINE SCRUBBERS
Normal Drum Position	Vertical
Allowable Vapor Velocity, % of V_c	
+ Without CWMS	Not Allowed
+ With CWMS(1)	100(2)
Liquid Holdup	The greater of: 1. Equal to or greater than the volume of a 50 ft (15 m) slug of liquid in the inlet piping. 2. Ten minutes holdup based on the largest liquid spill from upstream units.
Type of Nozzle Inlet (Vapor/Liquid)	Slotted tee distributor
Outlet (Vapor)	Flush

Liquid Holdup for LL and VLL Services

- Must allow adequate time for liquid – liquid separation in the bulk phases based on the following assumptions:
 - Each phase is dispersed in the other
 - Separation will occur if the holdup time of each phase is equal to or larger than the time required for the drops to rise or settle to the interface
- Time required for liquid – liquid separation obtained by dividing the liquid height of the bulk phase by the drop settling velocity of the other liquid phase
 - Droplet settling velocity is based on droplet size, Reynold's number, and the appropriate law (Stokes, Intermediate, or Newtown's)
 - The maximum separation velocity is 10 inches / minute (250 mm / min)
 - Droplet size can be found in Table 1, DP V-B

Drop Size for Drum Design

Light Liquid Phase Density	Heavy Liquid Phase	Drop Size, inches (mm) (Both Phases)
53 lb/ft ³ (850 kg/m ³) and lower	Water, Caustic, or Amine	0.005 (0.13)
Higher than 53 lb/ft ³ (850 kg/m ³)	Water, Caustic, or Amine	0.0035 (0.089)

Liquid Holdup for LL and VLL Services (cont.)

- Minimum interface height based on liquid holdup for process, control, or emergency requirements.
- Settling pot may be used for small heavy liquid phase rate to reduce drum size
 - Size per DP V-B
 - Limits are:

Drum Diameter (D), in. (mm)	Pot Diameter, max.
$D \leq 40$ (1000)	$D/2$
40 (1000) $< D < 60$ (1500)	20 in. (500 mm)
$D \geq 60$ (1500)	$D/3$

Separation Velocity Equations

		RANGE OF APPLICABLE REYNOLDS NUMBERS, Re
Stokes' Law:	$V_S = (C_1) \left(\frac{d^2 \Delta S}{\mu} \right)$	$Re < 2$
Intermediate Law:	$V_S = (C_2) \left[\frac{(d)^{1.143} (\Delta S)^{0.714}}{(\mu)^{0.429} (S_c)^{0.286}} \right]$	$Re \geq 2 \leq 500$
Newton's Law:	$V_S = (C_3) \left(\frac{d \Delta S}{S_c} \right)^{0.5}$	$Re > 500$
	$Re = C_4 \frac{d V_S S_c}{\mu}$	

where: V_S = Settling velocity of dispersed phase droplets or bubbles, in./min (mm/s)

C_1 = Constant = 8.3×10^5 for Customary units (544 for Metric units)

C_2 = Constant = 1.03×10^4 for Customary units (108 for Metric units)

C_3 = Constant = 2.05×10^3 for Customary units (172 for Metric units)

C_4 = Constant = 10.74 for Customary units (0.999 for Metric units)

d = Diameter of dispersed phase droplet or bubble, in. (mm)

ΔS = Difference in specific gravities of continuous and dispersed phases (with respect to water at 60°F), dimensionless (absolute value)

S_c = Specific gravity of continuous phase at conditions, dimensionless

μ = Viscosity of continuous phase at conditions, cP (mPa·s)

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Droplets – The Bottom Line in EMoDrum

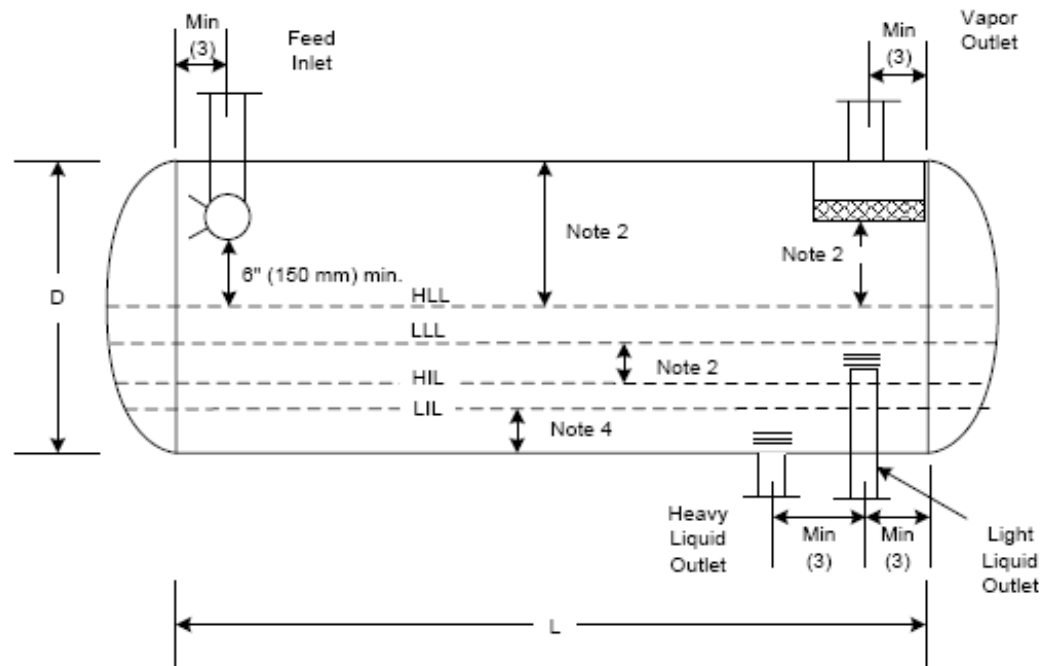
- Both droplet formation mechanism and droplet size impact settling / drum design
- Vapor – droplet formation type affects the amount of liquid that is not removed from the vapor phase
 - Use of a CWMS can often remove the rest of the liquid droplets
- Liquid – droplet size affects the settling velocity of liquid droplets in the bulk phase
 - Larger droplets will settle faster

LL and VLL Interface Levels

- HLL – High Liquid Level (Light Phase)
- LLL – Low Liquid Level (Light Phase)
- HIL – High Interface Level
- LIL – Low Interface Level

- Calculate settling time for light phase droplets to reach interface using the LIL to heavy liquid outlet nozzle height

- Calculate settling time for heavy phase droplets to reach interface using HIL to light liquid outlet nozzle

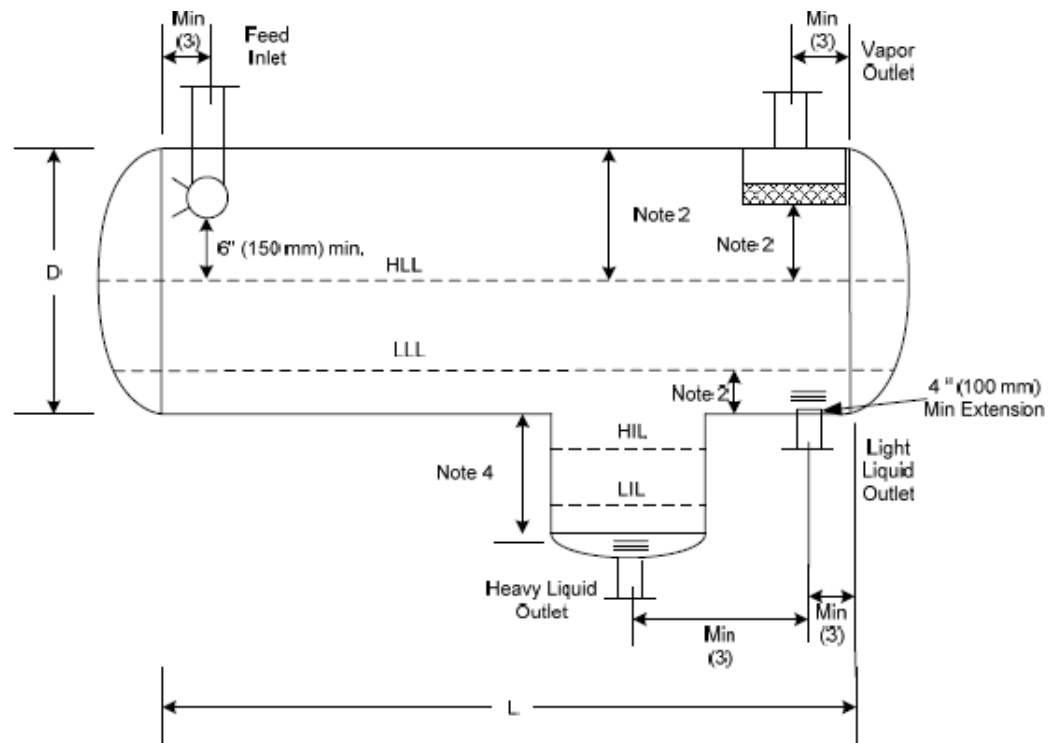


LL and VLL Interface Levels w/ Pot

- HLL – High Liquid Level (Light Phase)
- LLL – Low Liquid Level (Light Phase)
- HIL – High Interface Level
- LIL – Low Interface Level

- Calculate settling time for light phase droplets to reach interface using the LIL to heavy liquid outlet nozzle height

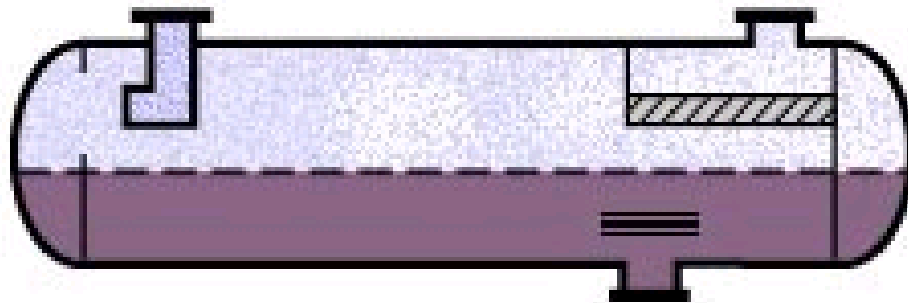
- Calculate settling time for heavy phase droplets to reach interface using HIL to light liquid outlet nozzle



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Anti-Vortex Baffles

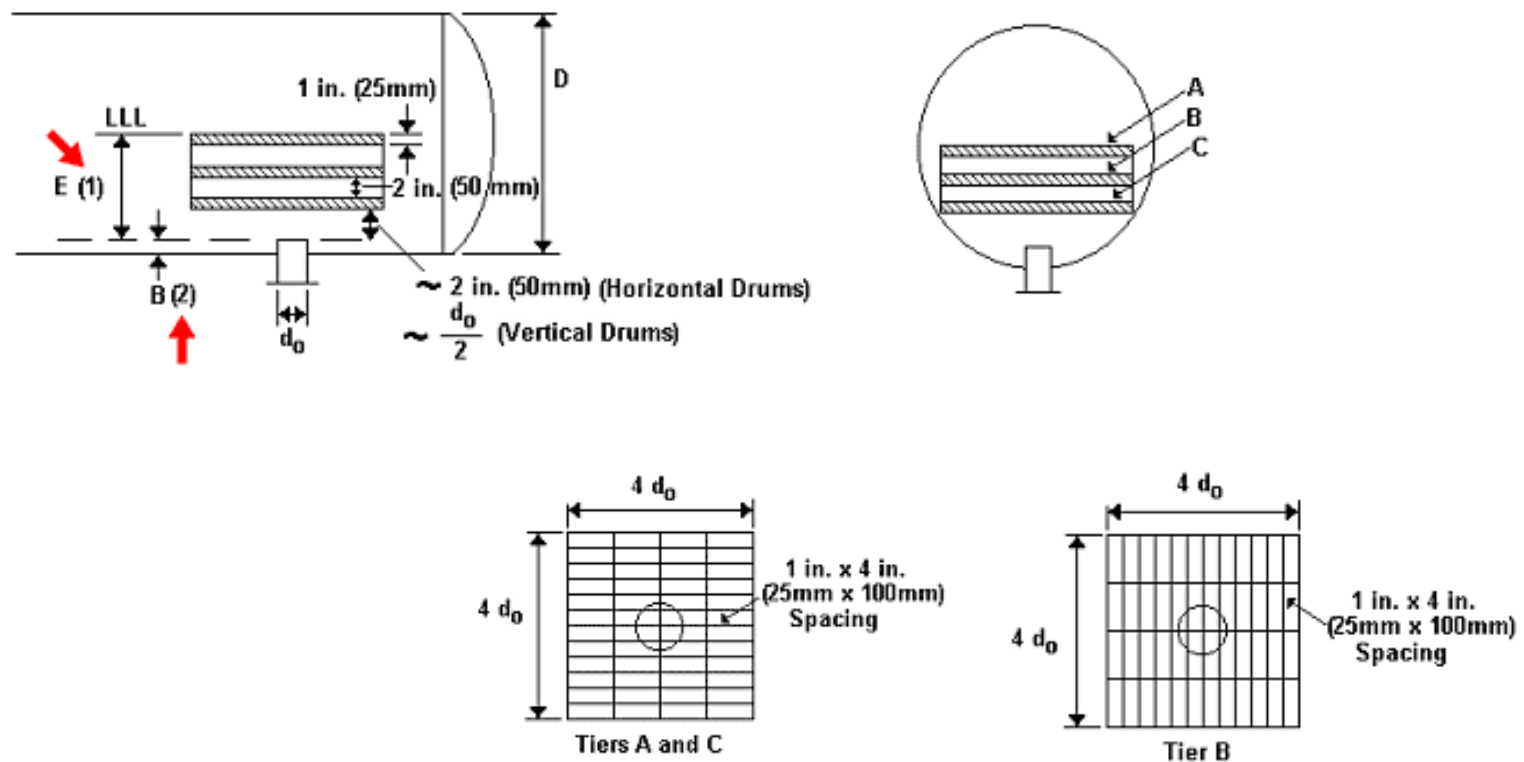
- An anti-vortex baffle is recommended for all liquid outlets. An anti-vortex baffle prevents the swirling action (as when a bathtub is drained) in the outlet nozzle that can trap vapor in the liquid and result in "gassing up" the pump.
- In circumstances where a baffle can not be used (plugging problems mainly), generous outlet sizing can avoid vapor entrainment (see DP III-H for Self-Venting Flow calculations).
- In EMOdrum, the minimum baffle length is based on the outside diameter of the nozzle and rounded up to the nearest inch.



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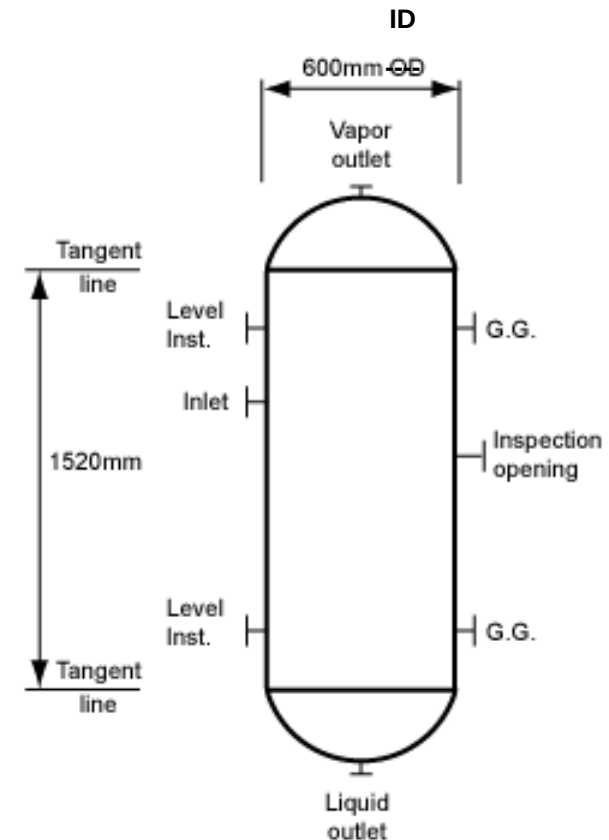
Anti-Vortex Baffle Construction

- Anti-vortex baffles are designed in accordance with GP 5-2-1.



Drum Dimensions

- Choosing length and width dimensions is a trial and error exercise which seeks to achieve a balance between different length/width combinations that meet the vapor-liquid volume requirements and cost or plot space.
- These rules of thumb are helpful when selecting drum dimensions:
 - A 3:1 or 4:1 length/diameter (L/D) ratio is usually optimum. As design pressure increases the optimum L/D ratio becomes greater.
 - The drum or vessel diameter should always be changed in standard 6" (150 mm) increments to permit use of standard size vessel heads.
- EMoDrum in PEGASYS will perform iterations to set optimal length / diameter
 - Step-by-step procedures in DP V-A



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Problem 6 – Part A

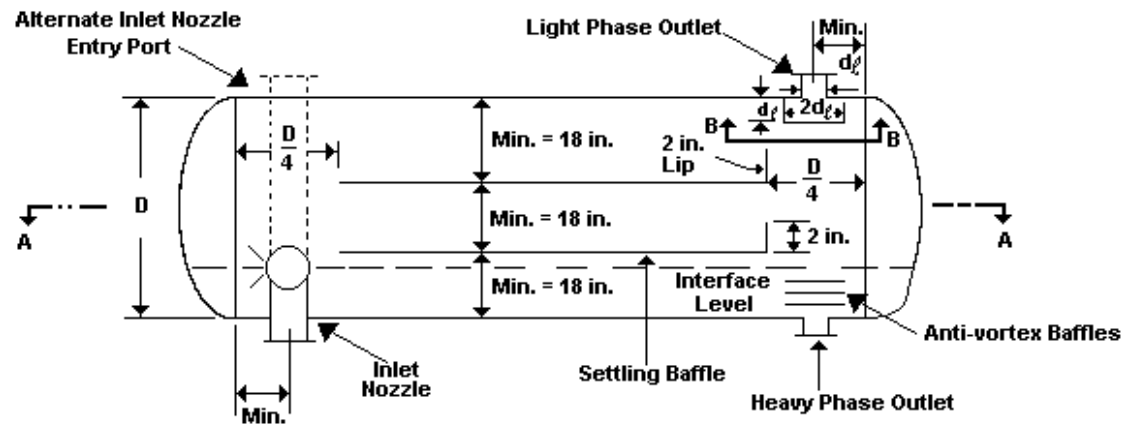
Improved Separation with Mechanical Means

- Additional drum internals may be used to improve separation, reduce required settling time, or reduce drum volume
- Typical types are:
 - CWMS
 - Settling Baffles
 - Perforated Plate
 - Grid / coalescing packing in the liquid phase
- Contact your EMRE separations specialist for the last 2 on the list or other mechanical separation devices

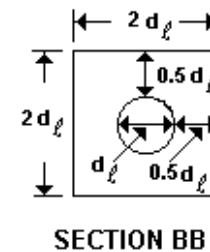
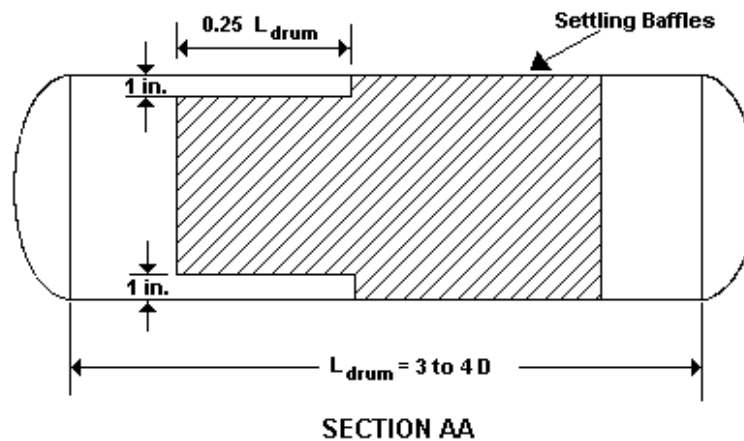
Horizontal Settling Baffles

- Used to reduce the distance the droplets must travel
 - Reduces required holdup time for separation in the liquid phases
 - Reduces drum volume / size
- Liquid holdup time between adjacent baffles should be equal to or larger than the time required for the drops to travel the vertical distance between the baffles
- Vertical spacing of baffles depends on horizontal velocity of the phase in which the baffles are installed, baffle length, and drop settling velocity
 - 18" (460 mm) minimum spacing between baffles required for access
- Baffles are sloped to facilitate drainage
- Lip on end of baffle is dependent on droplet phase limiting separation capacity
 - Light phase droplets limit capacity, lip is placed on the underside of baffle
 - Heavy phase droplets limit capacity, lip is placed on the topside of baffle
- See DP V-B for equations and all design requirements

Horizontal Settling Baffles

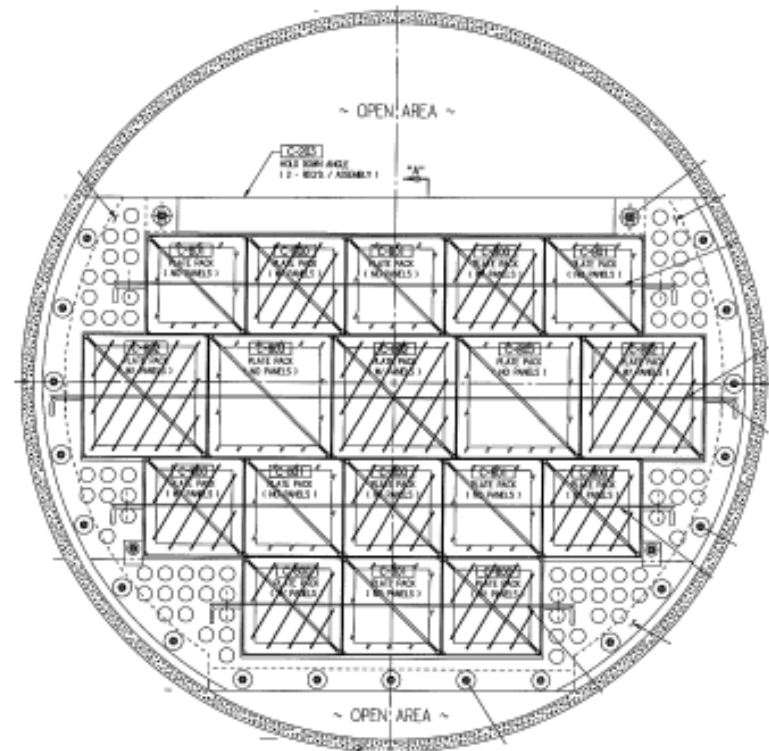


- Orientation of lip shows heavy phase droplets are limiting settler capacity

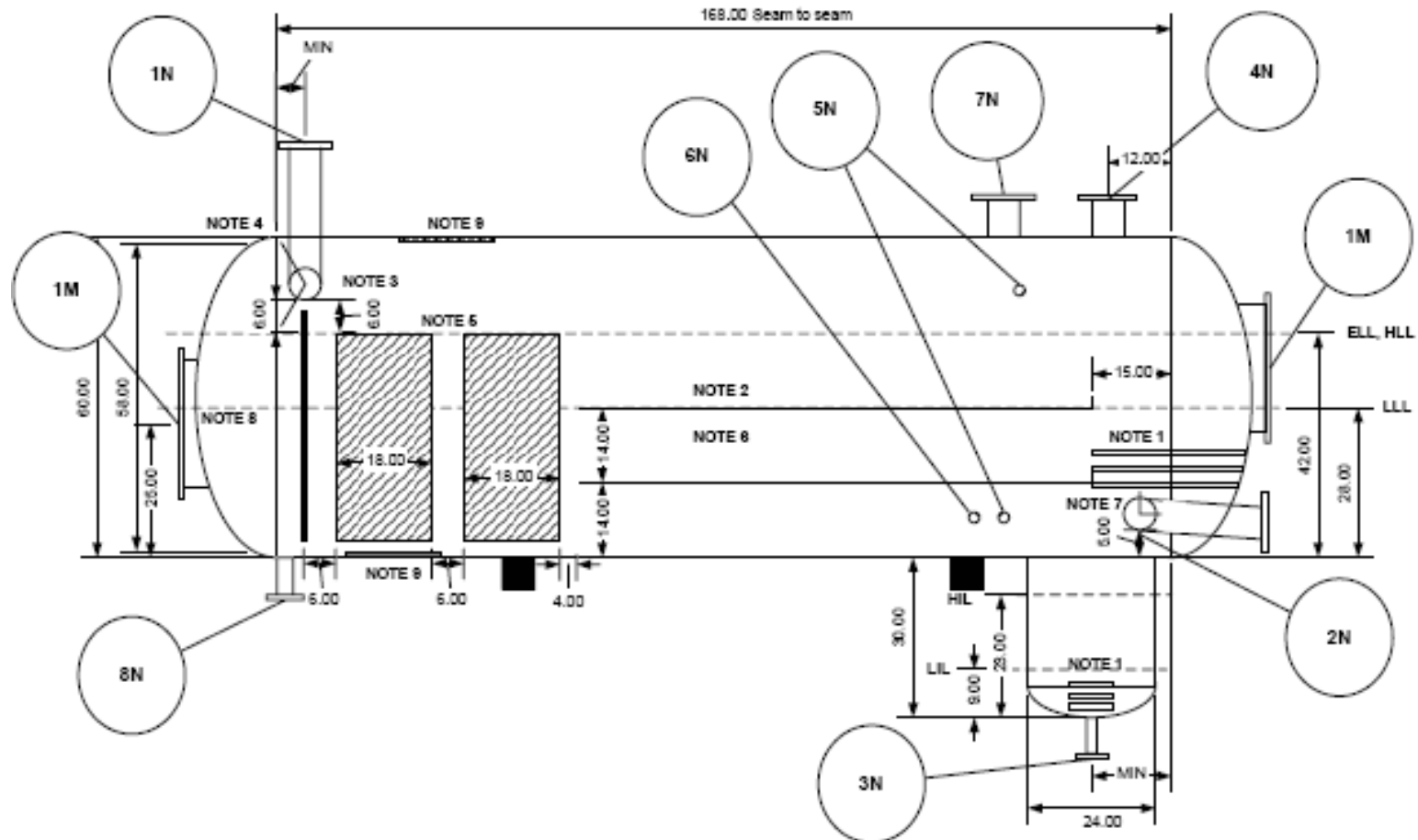


Perforated Plate / Settling Grid

- Located on inlet side of drum
- Droplet size increases reducing settling time
 - Additional surface area for liquid droplets to coalesce
- Revamp scenarios
 - Work with EMRE specialist
- Designed / provided by tower vendor



Revamp Three Phase Separator with Internals



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Special Services

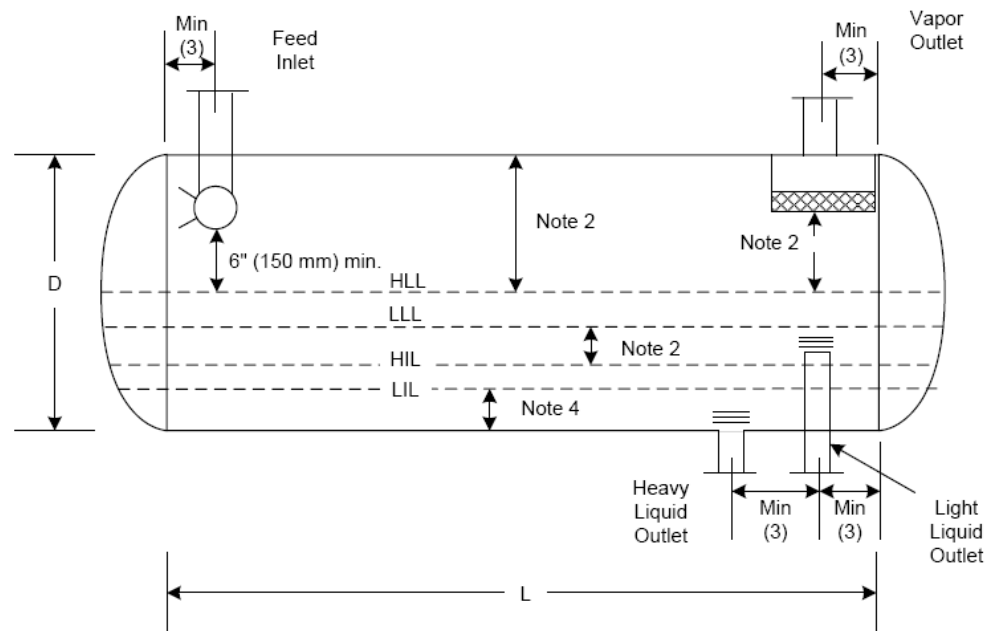
- Both DP V-A and V-B provide lots of specifics for special services
 - Crude flash drums
 - HP separators
 - Fuel gas / compressor suction KO drums
 - Amine / sour water feed drums
- Compressor Suction KO Drums
 - Requires additional CWMS height / density
 - Must account for all process conditions (including special operating modes)
 - Level high alarms and level high cutouts
 - Distance from drum to compressor minimize, piping insulated and sloped towards drum
- Amine Regenerator Feed / Sour Water Feed Drums
 - Use special three-phase separator design
 - Additional settling time required (30+ minutes)

Typical Design Criteria for Various Services

DESIGN PARAMETER	FEED SEPARATOR DRUMS FOR AMINE SCRUBBERS	HIGH-PRESSURE SEPARATORS	HORIZONTAL CRUDE FLASH DRUM	VERTICAL CRUDE FLASH DRUM
Normal Drum Position	Vertical	Horizontal or Vertical(4)	Horizontal	Vertical
Allowable Vapor Velocity, % of V_c + Without CWMS + With CWMS(1)	Not Allowed 100(2)	100(5) 100-125(2)	40(drum), 180(chevron) 40(drum), 100(CWMS)	40(drum & chevron) 40(drum & CWMS)
Liquid Holdup	The greater of: 1. Equal to or greater than the volume of a 50 ft (15 m) slug of liquid in the inlet piping. 2. Ten minutes holdup based on the largest liquid spill from upstream units.	Adequate for complete separation of 220 μ m bubbles based on settling (rising) rate equations given in DP V-B . Minimum height at low liquid level = 18 in. (450 mm). Minimum hold-up below LLL for HP resid = 2 minutes.	Liquid holdup at NLL should be 5 minutes. Minimum vertical height in the vapor space above the HLL should be 25% of the drum diameter. The minimum holdup time between the HLL and NLL is 1 minute. Minimum height and holdup time between the bottom of the drum and the LLL is 3 ft (900 mm) and 2 minutes, respectively.	Liquid holdup at NLL should be 5 minutes. The minimum holdup time between the HLL and NLL is 1 minute. Minimum height and holdup time between the bottom of the Drum and the LLL is 3 ft (900 mm) and 2 minutes, respectively.
Type of Nozzle Inlet (Vapor/Liquid)	Slotted tee distributor	Slotted tee distributor (split flow)	Slotted tee distributor	Horizontal tangential with annular ring
Outlet (Vapor)	Flush	Flush	Flush	Flush
Outlet (Liquid)	Flush	Flush	Flush	Flush
Special Considerations	See <i>MEA Scrubber Feed Separator Drums</i> under DESIGN CONSIDERATIONS FOR SELECTED SERVICES .	See <i>High-Pressure Separators</i> under DESIGN CONSIDERATIONS FOR SELECTED SERVICES .	See <i>Crude Preheat Flash Drums</i> under DESIGN CONSIDERATIONS FOR SELECTED SERVICES .	See <i>Crude Preheat Flash Drums</i> under DESIGN CONSIDERATIONS FOR SELECTED SERVICES .

Typical Three Phase Separator

Figure 5
Horizontal Three Phase Separator with Liquid Level Interface Control

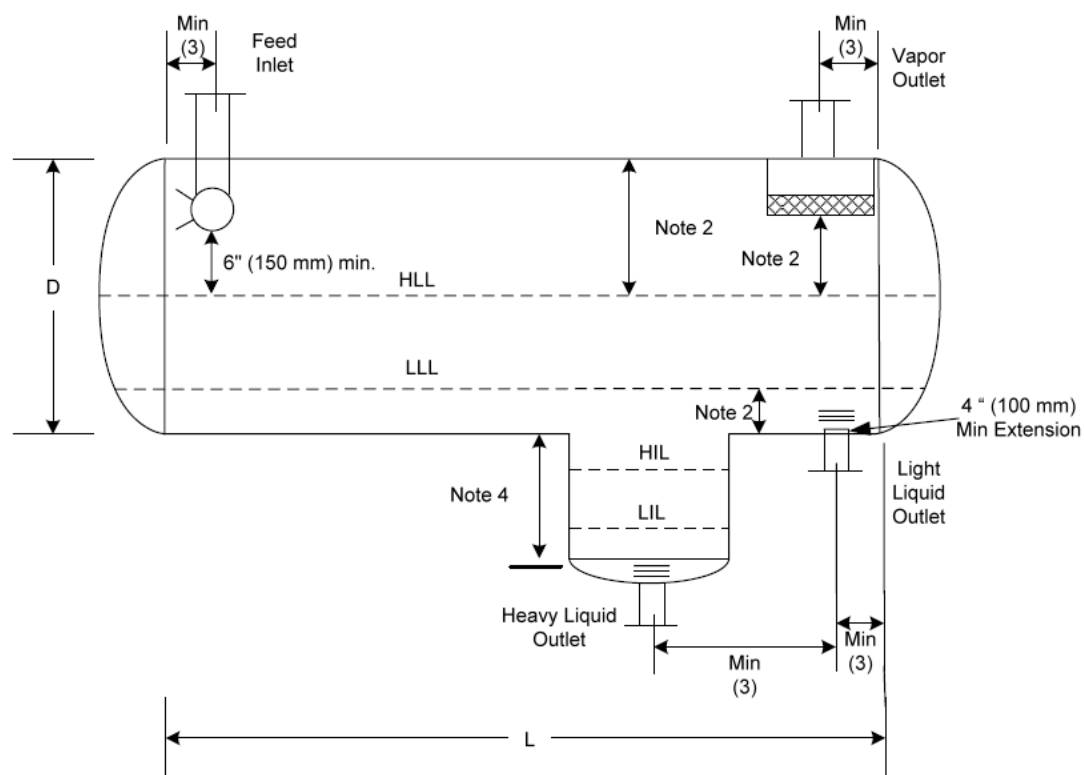


DP5BFB

Notes:

- (1) Slotted tee inlet distributor should be used for this service.
- (2) See design guidelines in [DP V-A](#).
- (3) Minimum distance considering reinforcement and fabrication requirements given in [GP 05-01-01](#) and [GP 05-01-02](#).
- (4) See [Equation \(3\)](#).
- (5) Provide anti-vortex baffles per [GP 05-02-01](#).
- (6) Provide one manway at end of drum opposite to vent nozzle. Manway and vent should be designed according to criteria given in [GP 05-01-01](#). Manways on the vessel head near inlets should have removable plugs in the manway nozzle to minimize turbulence at the inlets.

Typical Three Phase Separator w/ Settling Pot



DP5BFB

Notes:

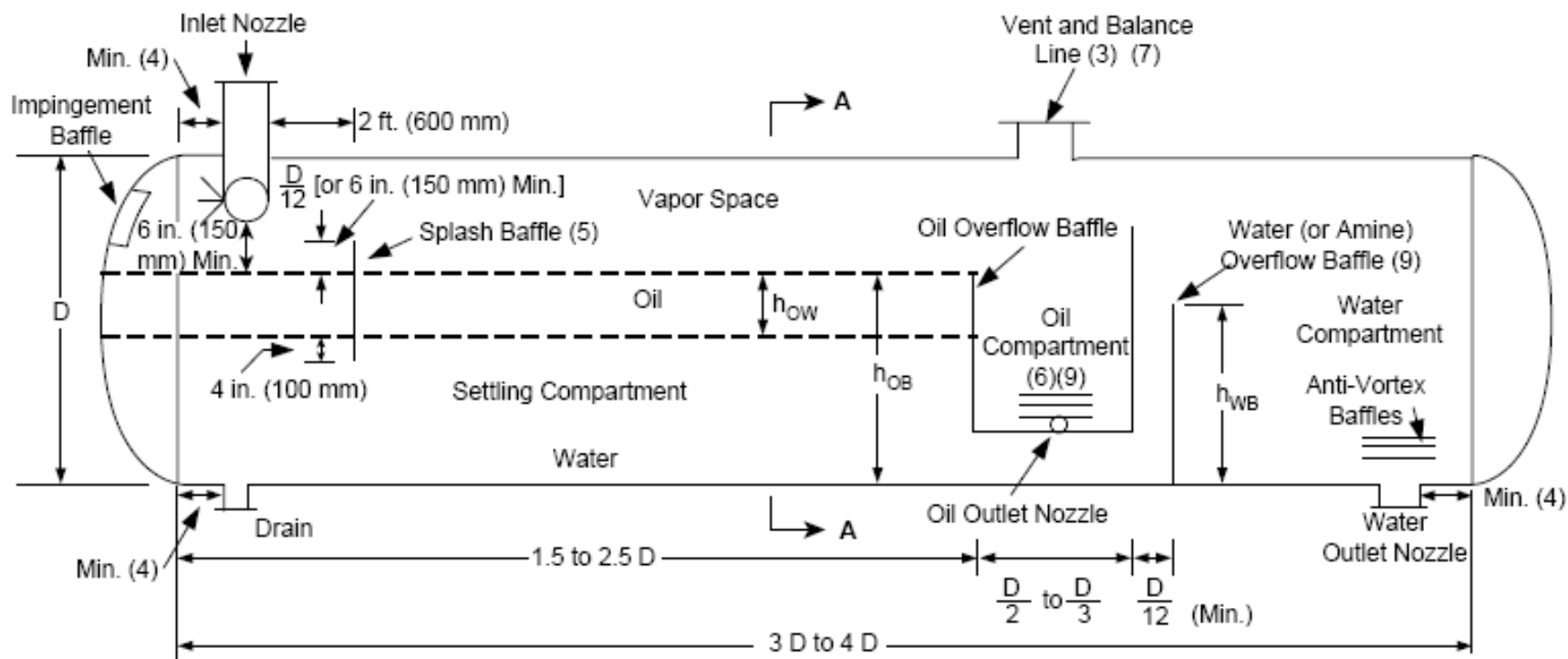
- (1) Slotted tee inlet distributor should be used for this service.
- (2) See design guidelines in [DP V-A](#).
- (3) Minimum distance considering reinforcement and fabrication requirements given in [GP 05-01-01](#) and [GP 05-01-02](#).
- (4) See design guidelines in [DP XII-C](#), Figure 20.
- (5) Provide anti-vortex baffles per [GP 05-02-01](#).
- (6) Provide one manway at end of drum opposite to vent nozzle. Manway and vent should be designed according to criteria given in [GP 05-01-01](#). Manways on the vessel head near inlets should have removable plugs in the manway nozzle to minimize turbulence at the inlets.

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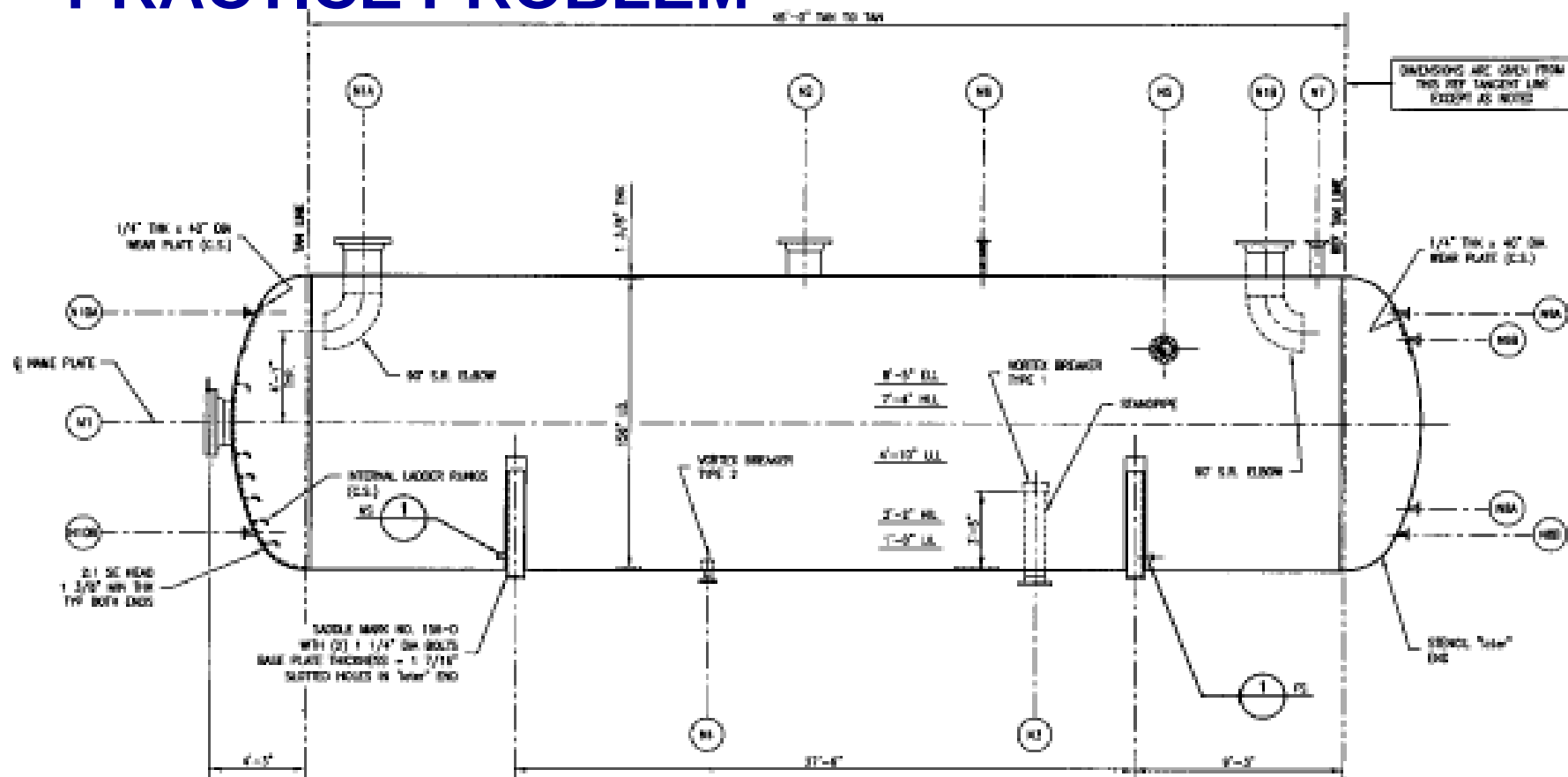
Three Phase Separator w/ Internal Box

- An internal box is used to collect the light phase while an overflow weir allows the heavy phase to enter a segregated drawoff box
- Typically used when
 - Liquid phase volume is small compared to heavy phase
 - Interface control may be difficult
 - Emulsions
 - High specific gravity oil
- Amine regenerator or sour water feed drums are typical applications
 - Large aqueous phase, small hydrocarbon phase
 - Emulsions are likely, separation is difficult
 - Must provide at least 9" (230 mm) between the oil / water interface and the top of the oil overflow weir
- Specific criteria for velocity under the box and between the box and overflow baffle provided in DP V-B.

Amine Regenerator / Sour Water Feed Drums



PRACTICE PROBLEM



"Water" SIDE ELEVATION

[illegible]

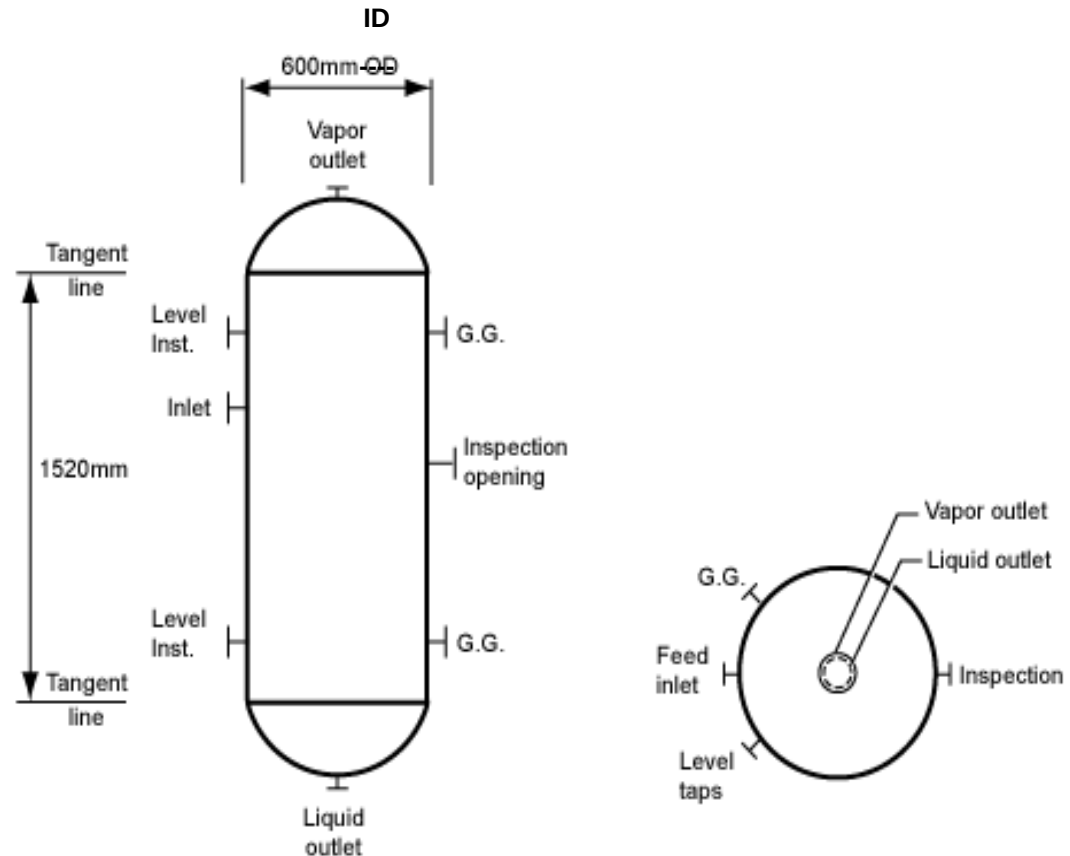
BT LSM 3 PHASE SEPARATOR – WHAT SHOULD BE CHANGED?

Slide 8.57

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Beginning the Drum Design Sketch

- As the last step of drum design, a sketch is prepared.
- The first information in the sketch includes:
 - orientation
 - elevation
 - nozzles
 - internals

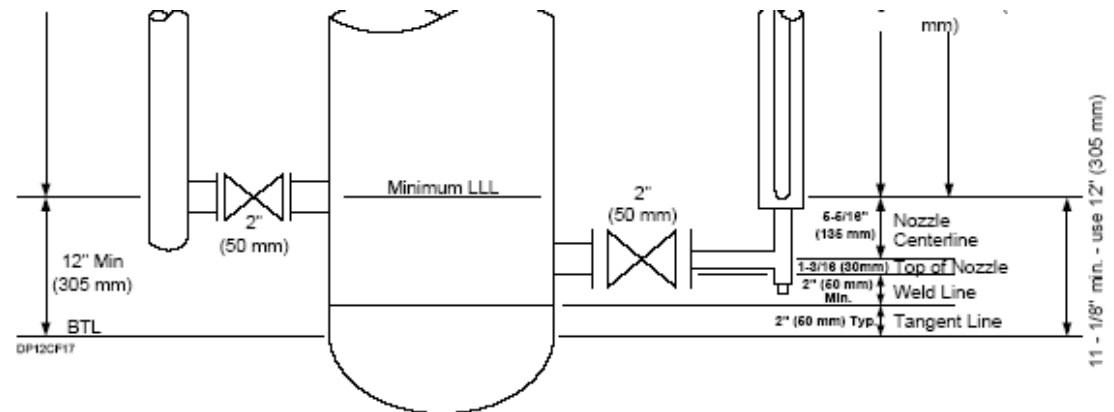


Level Instrumentation and Other Information

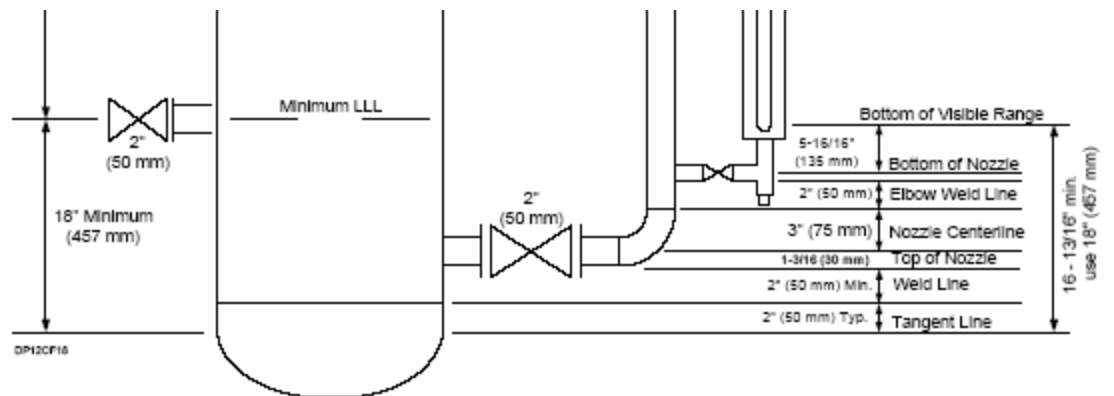
- One of the final items to consider is liquid level measurement.
 - External displacers measure the change in buoyancy of the displacer tube as the level changes over the length of the tube.
 - Normally, the gauge glass taps should ensure that the visible range spans the full range of the drum level or at least the range of the level instrument. The gauge glass sections may be stacked.
- Besides the instrumentation information, the completed drum design includes:
 - Design and operating pressures and temperatures
 - Positions of interface (LLL,HLL, and ELL, if required)
 - Materials of construction

LLL at Tower Bottom

- Mechanical limits prevent LLL at vessel tangent line
 - Direct connection: 12" minimum for normal displacers and gauge glasses
 - Check whether site prefers bridle or direct connection



- Bridle or level span > 12": 18" minimum



LLL at Drum Bottom

- Nozzle location moves LLL to about 24" (610 mm) from drum bottom
 - See previous slide for distance from nozzle to LLL
 - Can cheat by placing nozzle on boot if necessary
 - Note this is not a requirement. Nozzle can be installed less than 12" (305 mm) if necessary, it is just more difficult.
 - Avoid connections to bottom of vessels. They plug.
 - Other types of level instruments may require less distance

Figure 20
Minimum Instrument Connection Dimensions for Horizontal Vessel/Boot



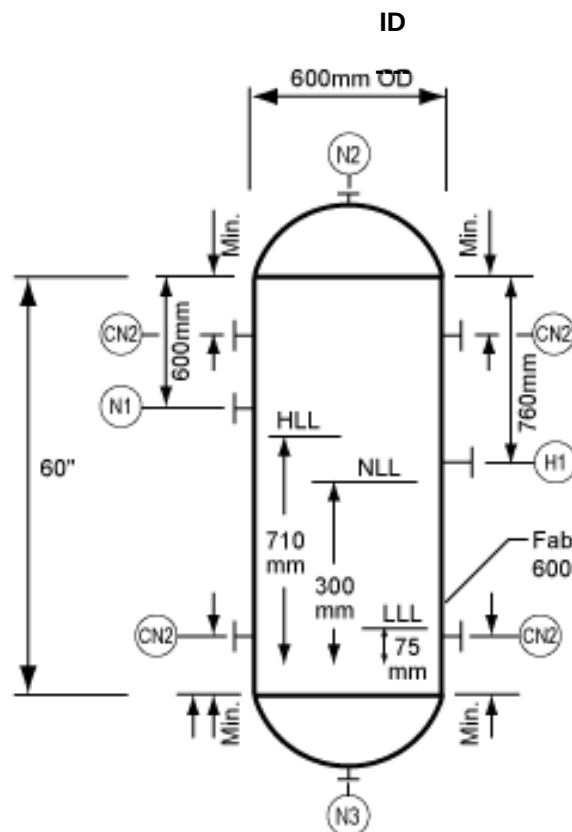
Vessel Design

- Nozzles normally minimum 2"
 - 2" min required for instruments (GP 5-1-1 para. 7.7.1.3)
 - Many GII's require 2" min nozzles
- Include maximum differential pressure, static and dynamic
 - The added pressure at the bottom of the vessel
 - Normally design "water full" (GP 5-1-1)
 - Could also check maximum liquid level plus tray delta P
 - Include "FV" – Full Vacuum, if required

DESIGN CONDITIONS:

DESIGN PRESSURE:	500 PSIG & FV
DESIGN TEMPERATURE:	232°F
MAXIMUM DIFFERENTIAL PRESS.	10 PSI

Completed Drum Design Drawing

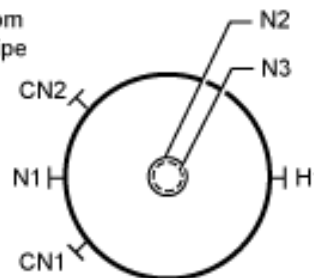


Nozzle Schedule

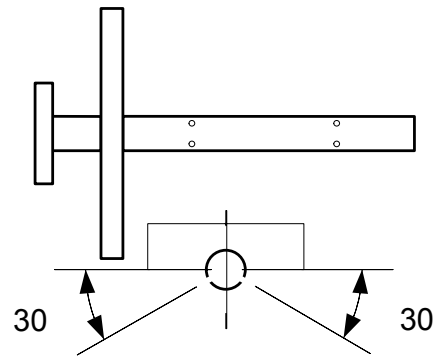
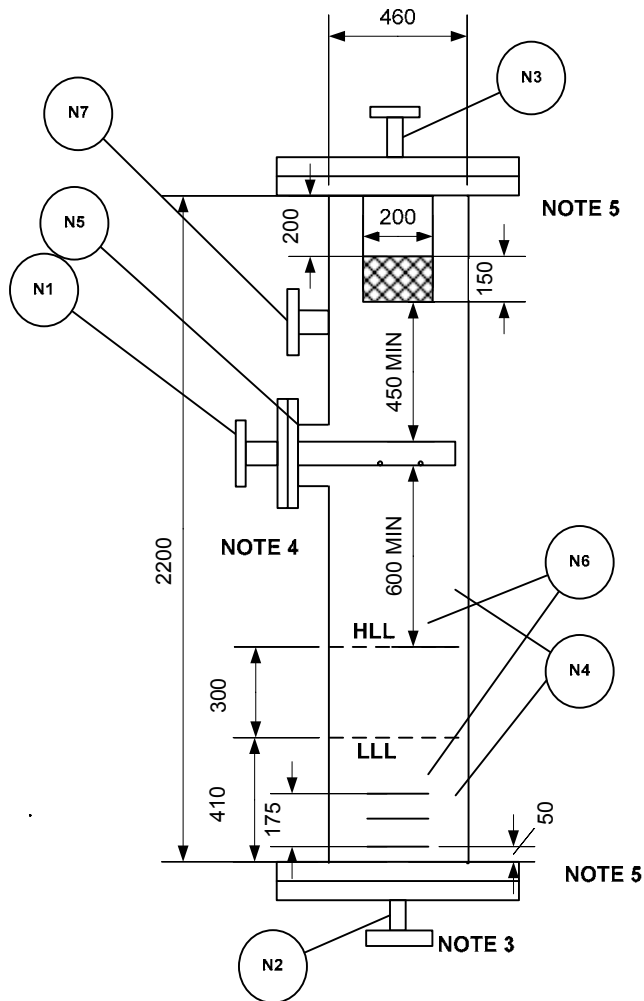
Item	Req'd	Size	Ratg	Fittg	Service
N1	1	100mm	600#	FLG	Inlet
N2	1	75mm	600#	FLG	Vap. Outlet
N3	1	100mm	600#	FLG	Liq. Outlet
H1	1	200mm	600#	FLG	Inspection (Opposite Levels Taps)
CN1	2	25mm	600#	FLG	Level Instrument
CN2	2		600#	FLG	Level G.G.

	Operating	Design
Temp. - °C	32	232
Press - kPa	1379	1655

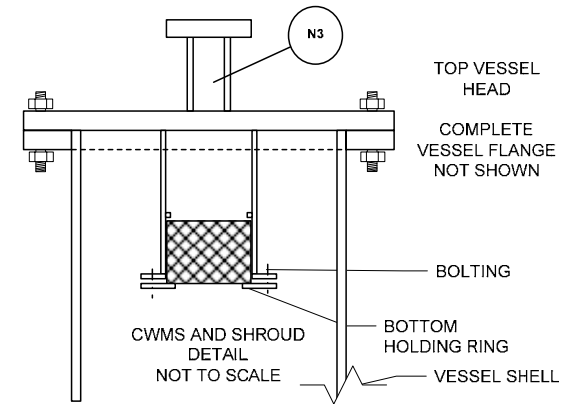
Mat'l of Construction - CS
 Corrosion Allow - SCH 40 Pipe
 Insulation - None
 All Dimensions in mm



Small Drum Example



DISTRIBUTOR DETAIL



- No manway
- All internals are removable
- Drum made from piping
 - Flanged head not required – can be pipe cap
- CWMS sized for 100% Vc

Other References

- EE.5E.93 GUIDE FOR APPLYING COALESCING MEDIA TO DEBOTTLENECK EXTRACTORS, LIQUID-LIQUID SETTLERS AND SAND FILTERS
- EE.96E.75 DISTILLATE DRYING HANDBOOK
- EE.43E.99 VERTICAL DRUM DEBOTTLENECKING FOR VAPOR/LIQUID SERVICES

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