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Practical Engineering Guidelines for Processing Plant Solutions

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KLM Technology Group
#03-12 Block Aronia,
Jalan Sri Perkasa 2
Taman Tampoi Utama
81200 Johor Bahru.
Malaysia

# SEPARATOR VESSEL SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINE)

Author:
Viska Mulyandasari

Checked by:
Karl Kolmetz

## TABLE OF CONTENT

INTRODUCTION

Scope

Heterogeneous Separation

Separator Vessel

Two Phase Separator

Three Phase Separator

GENERAL DESIGN CONSIDERATION

Vessel Orientation

General Separator Design Consideration

General Separator Design Criteria

Equipment Protection Requirements

Equipment Protection Requirements

DEFINITIONS

NOMENCLATURE

THEORY

Gravity Separation (Sedimentation)

Centrifugation

Heads Selection

Material of Construction

Separator Vessel Sizing

APPLICATION

REFEREENCES

SPECIFICATION DATA SHEET

CALCULATION SPREADSHEET

## LIST OF TABLE


**Table 1.** Efficiency of centrifugal separator
**Table 2.** Coalescing media
**Table 3.** Coalescing media and their application
**Table 4.** Comparison of different gravity separator types
**Table 5.** Liquid retention time for 2-phase separator
**Table 6.** Typical retention time for 3-phase separator
**Table 7.** Recommended K value
**Table 8.** Separator K value
**Table 9.** Liquid holdup and surge times
**Table 10.** Low liquid level height
**Table 11.** L/D ratio
**Table 12.** Cylindrical height and area conversion
**Table 13.** Wall thickness, surface area, and approximate vessel weight


## LIST OF FIGURE


**Figure 1.** General types of separator vessel
**Figure 2.** Major components of horizontal separator
**Figure 3.** Internal parts of (a) vertical separator and (b) horizontal vapor-liquid separator
**Figure 4.** Typical arrangement of gravity settler
**Figure 5.** Vertical coalescer
**Figure 6.** Horizontal coalescer
**Figure 7.** Horizontal 3-phase separator
**Figure 8.** Vertical 3-phase separator
**Figure 9.** Drag coefficient for rigid spheres
**Figure 10.** Typical vessel heads

## INTRODUCTION

### Heterogeneous Separation

Heterogeneous mixtures consist of two or more parts (phases), which have different compositions. These mixtures have visible boundaries of separation between the different constituents which can be seen with the naked eye and consist of substances that do not react chemically. These substances can be elements or compounds. Components of a mixture can be separated using one or more appropriate techniques.

The separation can be done physically by exploiting the differences in density between the phases. The phase separations likely to be carried out are:

- Gas–liquid (or vapor–liquid)
- Gas–solid (or vapor–solid)
- Liquid–liquid (immiscible)
- Liquid–solid
- Solid–solid

The principal methods for the separation of heterogeneous mixtures could be classified as:

1. Settling and sedimentation

   Sedimentation or settling can be used to separate any particle from any fluid, whether it is a liquid from a gas, a solid from a liquid, or a liquid from a liquid (with different densities). In settling processes, particles with higher density are separated from a fluid by gravitational forces acting on the particles.

   The separation of suspended solid particles from a liquid by gravity settling into a clear fluid and a slurry of higher solids content is called sedimentation.

2. Inertial and centrifugal separation

   This method is similar to sedimentation, but some forces are added in order to get a better separation. Inertial separation is done by giving the particles downward momentum, in addition to the gravitational force. In a centrifugal device, the centrifugal force is generated to increase the force acting on the particles. Particles that do not settle readily in gravity settlers often can be separated from fluids by centrifugal force.

Centrifugal separation results a much shorter period of time than could be accomplished solely by gravity. It has mainly been used to separate fluids in static state, i.e. specific volumes, which needed to be separated.

3. Electrostatic precipitation

   It is generally used to separate particulate matter that is easily ionized from a gas stream by using an electric charge. The principal actions are the charging of particles and forcing them to the collector plates. The amount of charged particulate matter affects the electrical operating point of the electrostatic precipitator.

4. Filtration

   Filtration is commonly the mechanical or physical operation which is used for the separation of solids from fluids (liquids or gases) by interposing a medium (a permeable fabric or porous bed of materials) through which only the fluid can pass. The solid can be retained on the surface of the filter medium, which is *cake filtration*, or captured within the filter medium, which is *depth filtration*.

5. Scrubbing

   This method is commonly used to separate gas-solid mixtures. Very high particles collection efficiencies are possible with venturi scrubbers. The main problem with venturi scrubbers is the high pressure loss across the device.

6. Flotation

   Flotation is a gravity separation process that exploits the differences in the surface properties of particles. The separation process is based on the use of very fine gas bubbles that attach themselves to the solid particles in suspension to make them buoyant and drive them toward the free surface of the liquid.

   Flotation is especially useful to separate very small particles or light particles with low settling velocities. A number of chemicals can be added to the flotation medium to meet the various requirements of the flotation process.

Flotation requires the generation of small bubbles which can be produced by:

a. *dispersion*, in which the bubbles are injected directly by some form of sparging system

b. *dissolution* in the liquid under pressure and then liberation in the flotation cell by reducing the pressure

c. *electrolysis* of the liquid

7. Drying

Drying is the removal of water moisture or moisture from another substance, by a whole range of processes, including distillation, evaporation and even physical separations such as centrifuges.

## Separator Vessel

Generally, there are two types of vessel in chemical processing service: those substantially without internals and those with internals. The first types are commonly used as an intermediate storage or surge of a process stream for a limited or extended period, or to provide a phase separation by settling. The second category includes the shells of equipment such as heat exchangers, reactors, mixers, fractionators, and other equipment whose housing can be designed and constructed largely independently of whatever internals are necessary.

Separator vessel thus simply means as a vessel or tank without internals to provide a phase separation. This separator vessel furthermore can be classified into several categories based on their function. However, generally the classification in this guideline as pictured on Figure 1 below.

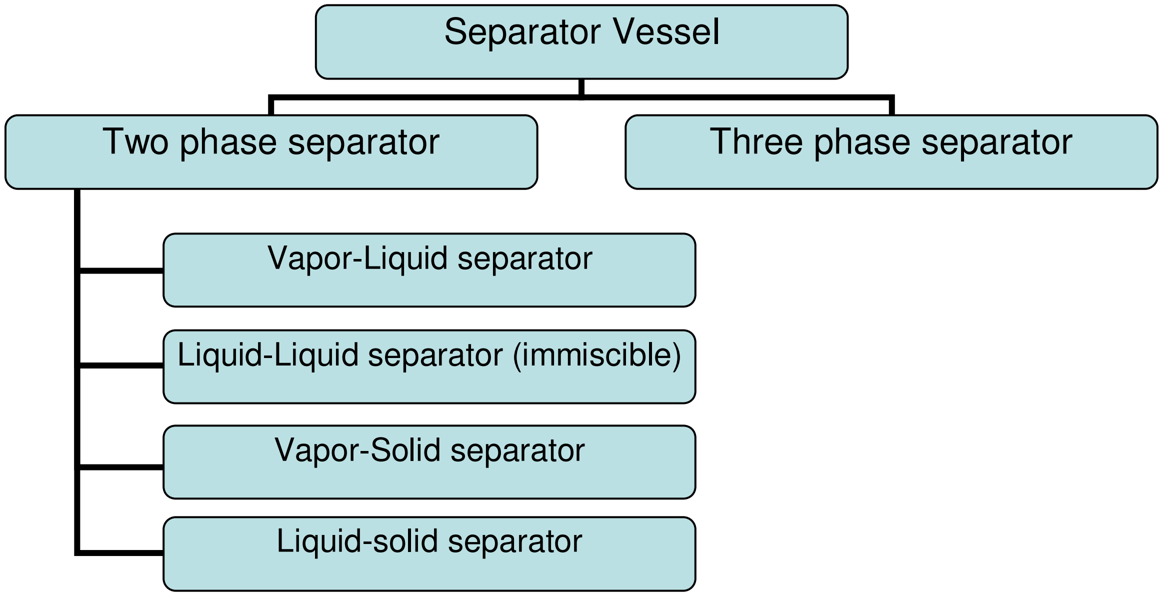


Figure 1. General types of separator vessel

Solid-solid separator is not included here since the separation process mostly takes part on a sieve, not in a vessel as the other phases separation. Separator vessels usually contain as follow:

1. Primary section.
2. Secondary section (gravity settling).
3. Coalescing section.
4. Sump or liquid collecting section.

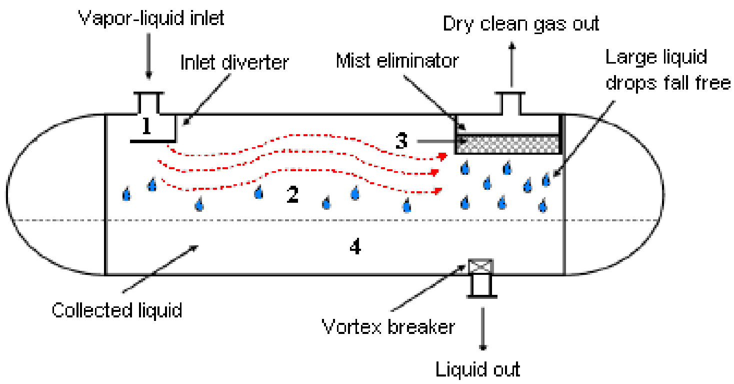


Figure 2. Major components of horizontal separator

Geometrically, all process vessels might be horizontal, vertical, or spherical. The horizontal and vertical types are commonly used, while the spherical separators are occasionally used for high pressure service where compact size is desired and liquid volumes are small.

**Two Phase Separator**

Vapor-Liquid Separator

A vapor-liquid separator is a vessel into which a liquid and vapor mixture is fed and wherein the liquid is separated by gravity, falls to the bottom of the vessel, and is withdrawn. The vapor travels upward at a design velocity which minimizes the entrainment of any liquid droplets in the vapor as it exits the top of the vessel.

Vapor-liquid separators are very widely used in a great many industries and applications such as:

- Oil refineries
- Natural gas processing plants
- Petrochemical and chemical plants
- Refrigeration systems
- Air conditioning
- Compressor systems for air or gases
- Gas pipelines

- Steam condensate flash drums

A vapor-liquid separator might consist simply of an empty vessel, which causes the fluid velocities in the entering pipe to be reduced by enlarging the cross-sectional area of flow. Usually, however the separator includes internal parts, to promote separation of the process, such as:

1. Primary separation section (entrance): for separating the bulk of the liquid from the gas. It is desirable to remove the liquid slugs and large droplets of liquid quickly from the gas stream, and to remove gas from the liquid.

2. Secondary separation section: for removing smaller particles of liquid by gravity settling depends to a large extent on the decreased gas velocity and reducing the turbulence of gas.

3. Liquid separation section (or the liquid accumulation section): for removing gas bubbles which may be occluded with the liquid, and for sufficient storage of the liquid to handle the slugs of liquid anticipated in routine operation.

4. Mist extractor or eliminator section: for removing from the gas entrained drops of liquid, which did not separate in the secondary separation section. Mist extractor might be used to decrease the amount of entrained liquid in the gas and to reduce diameter of the vessel.

5. Vortex breaker (in the bottom of the vessel): prevents potential pump suction problems if a pump is used to remove collected liquids.

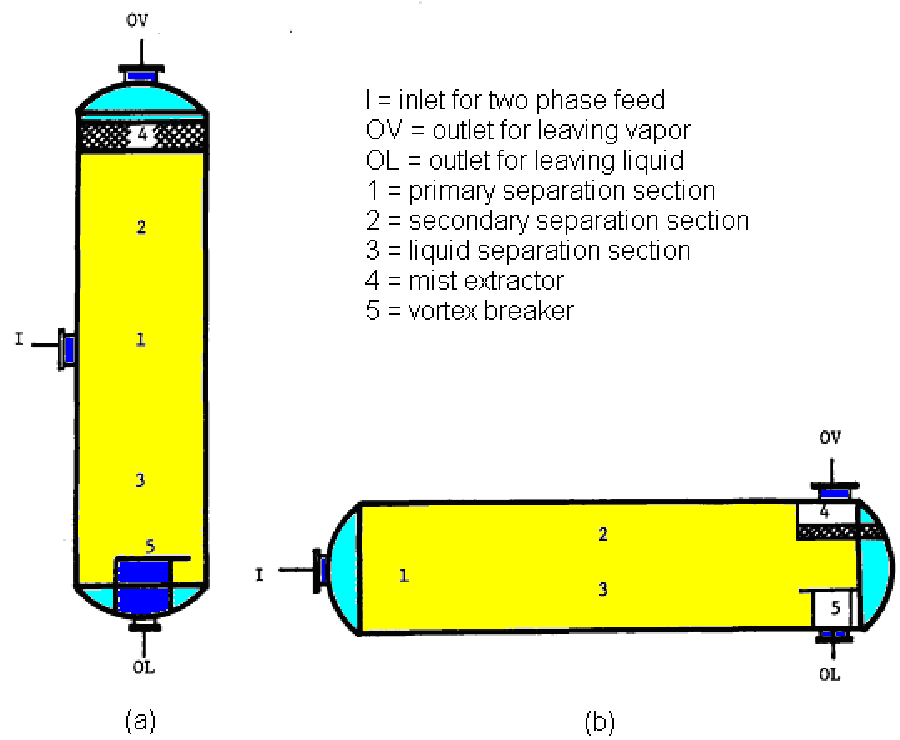


Figure 3. Internal parts of (a) vertical separator and (b) horizontal vapor-liquid separator

Separators may be designed with or without mist eliminator pads and may also have inlet diverters. Some separators may also have proprietary impingement or settling internals.

An inlet diverter produces the initial gross separation of liquid and vapor, as the sudden change in momentum occurs when the fluid enters the separator and hit it. Commonly, the inlet diverter contains a downcomer that directs the liquid flow below the oil or water interface. The inlet diverter assures that little gas is carried with the liquid. Some functions of inlet devices are:

- Reduces momentum of inlet stream
- Provides primary (bulk) separation of gas and liquid
- Enhances flow distribution of gas and liquid phases
- Prevents droplet shattering and re-entrainment of bulk liquid phases
- Stable liquid level control and reduced foaming

The impingement or settling internal might be added to optimized separation process. As the descriptive name suggests, the impingement separator allows the particle to be removed to strike some type of surfaces. There are basically three construction types for impingement separator: wire mesh, plates (curved, flat, or special shaped), and packed impingement beds.

The vapor-liquid separators which are generally used in industries might be classified into following:

1. Gravity separators

   The separation process in this gravity separator occurs by settling and sedimentation and depends on gravitational force. Liquid droplets or solid particles will settle out of a gas phase if the gravitational force acting on the droplet or particle is greater than the drag force of the gas flowing around the droplet or particle. The same phenomenon happens for solid particles in liquid phase and immiscible sphere of a liquid immersed in another liquid.

   Gravitational forces control separation; the lower the gas velocity and the larger the vessel size, the more efficient the liquid/gas separation. Because of the large vessel size required to achieve settling, gravity separators are rarely designed to remove droplets smaller than 300 microns.

   Gravity separators are not recommended as the soul source of removal if high separation efficiency is required.

   Gravity separators are sometimes also called *scrubbers* when the ratio of gas rate to liquid rate is very high. These vessels have a small liquid collection section and are recommended only for the following items:

   a. Secondary separation to remove carryover fluids from process equipment such as absorbers and liquid dust scrubbers.
   b. Gas line separation downstream from a separator and where flow lines are not long.
   c. Miscellaneous separation where the gas-liquid ratio is extremely high

2. Centrifugal vapor-liquid separators

   Utilize centrifugal action for the separation of materials of different densities and phases, might be built in stationary and rotary types. In centrifugal separators, centrifugal forces act on droplets at forces several times greater than gravity as it enters a cylindrical separator. Generally, centrifugal separators are used for removing droplets greater than 100 μm in diameter, and a properly sized centrifugal separator can have a reasonable removal efficiency of droplet sizes as low as 10 μm.

Centrifugal separators generally might be divided into three types: stationary vane separator, cyclone separator, and inertial centrifugal separator. Cyclones and knock-out drums are recommended for waxy or coking materials. The efficiency of each of three types can be estimated using Table 1 below.

**Table 1. Efficiency of centrifugal separator**

| Types | Efficiency Range |
| --- | --- |
| High velocity stationary vanes | 99% or higher of entering liquid. Residual entrainment 1 mg/kg (ppm) or less. |
| Cyclone separator | 70-85% for 10 micrometers, 99% for 40 micrometers, and larger. For high entrainment, efficiency increases with concentration. |
| Rotary | 98% for agglomerating particles |

3. Vapor-liquid filter separators

They are used in separation of liquid and solid particles from gas stream. Gas filter separator has a higher separation efficiency than the centrifugal separator, but it uses filter elements which must periodically be replaced. Typical applications of gas filter separators are as follows:

- Compressor stations to protect compressors from free liquid and prevent cylinder wear from solids.
- Metering and pressure reduction stations at city gates: to remove liquid hydrocarbons, water, sand and pipe scale.
- Protection of desiccant beds and collection of dust carry-over from beds.
- Gas storage systems: to prevent injection or withdrawal of solids, dust, and small amounts of liquids.
- Fuel lines to power plants and engines.

Liquid-Liquid Separator

Separating liquid-liquid dispersions can be difficult depending on the physical properties of the two liquid phases. The specific gravity, viscosity and interfacial tension (IFT) of the two liquid phases are important parameters in determining how easy two liquids can be separated.

Liquid-liquid separator might be divided into two broad categories based on their operation. The first is defined as “gravity separation” where the two immiscible liquid phases separate within the vessel by the differences in density of the liquids.

Differences in densities of the two liquids cause droplets to rise or fall by their buoyancy. The greater the difference in densities, the easier the separation becomes. Rising (or falling) droplets are slowed by frictional forces from viscous effects of the opposing liquid. Sufficient retention time must also be provided in the separator to allow for the gravity separation to take place.

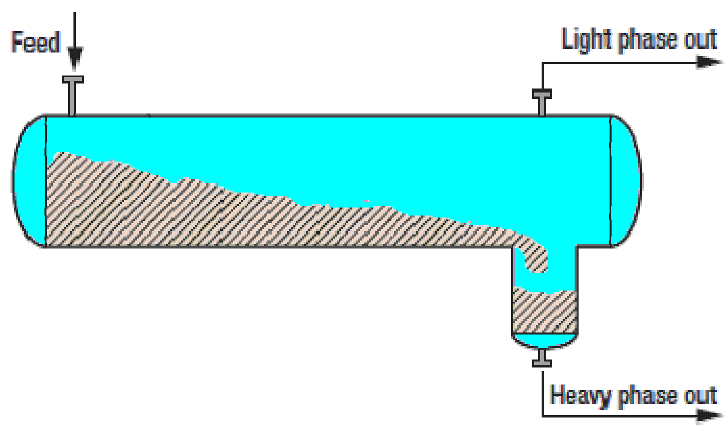


Figure 4. Typical arrangement of gravity settler

The second category is defined as “coalescing separation”. This is where small particles of one liquid phase must be separated or removed from a large quantity of another liquid phase. Liquid-Liquid coalescers are used to accelerate the merging of many droplets to form a lesser number of droplets, but with a greater diameter. Settling of the larger droplets downstream of the coalescer element then requires considerably less residence time. There are three-step methods of coalescing separation: collection of individual droplets; combining of several small droplets into larger ones; and rise (or fall) of the enlarged droplets by gravity.

This application is common in the quench section, compression section and hot fractionation section. The coalescers might be designed vertically or horizontally. The vertical design is used to separate water from hydrocarbons when the interfacial tension is greater than 3 dyne/cm. In the horizontal configuration, a settling zone achieves separation by gravity. This configuration is used when the interfacial tension is less than 3 dyne/cm or for the separation of oil from the water phase.

Here is a picture of vertical and horizontal coalescer.

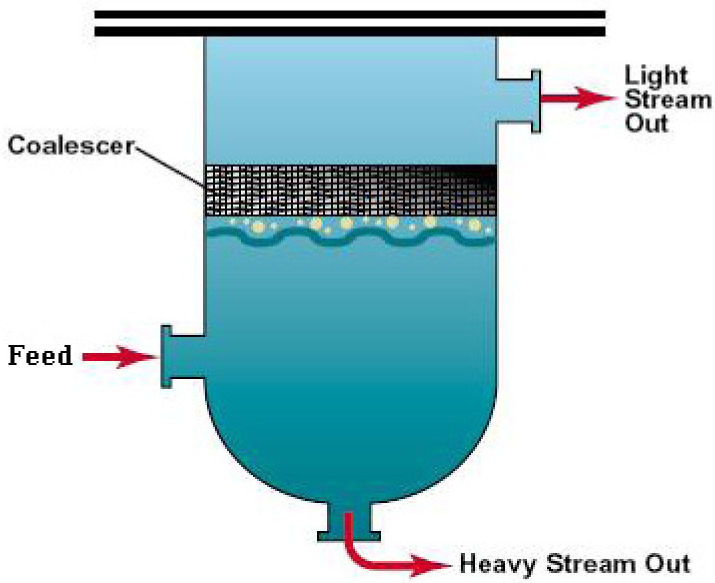


Figure 5. Vertical coalescer

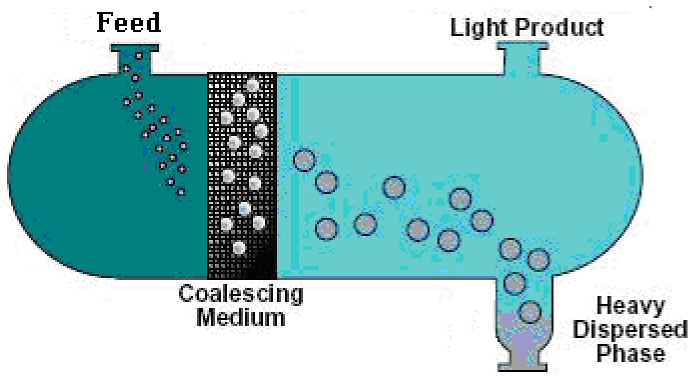


Figure 6. Horizontal coalescer

Different coalescing materials have been found suitable for different applications. Commercially, fiberglass seems to be the most popular medium due to its availability and low cost. Table 3 below shows different coalescing medias with their different surface properties, cost and fouling properties.

**Table 2. Coalescing media**

| Media | Surface Characteristic | Porosity | Size | Fouling/Cost |
|---|---|---|---|---|
| Metal/plastic corrugated sheets | hydophilicity, oleophilicty | 98-99% | 9,5-25,4 mm Spacing/Crimps | Low/Low |
| Wire/plastic mesh | hydophilicity, oleophilicty | 95-99% | 0,05-0,279 mm | |
| Wire wool | hydophilicity | 95-99% | 0,05-0,279 mm | |
| Wire/polymer co-knits | oleophilicty | 94-98% | 21-35 μm | |
| Wire/fiberglass co-knits, glass mat | hydophilicity | 92-96% | 9-10 μm | High/High |

In addition to the numerous coalescing media, Table 4 presents some coalescing media and their industrial applications with regard to the nature of emulsions they separate (emulsion source), flowrate and maximum droplet diameter.

**Table 3. Coalescing media and their applications**

| Media | Source | Max. Droplet Diameter (µm) | Flow Range ($gpm/ft^2$) |
|---|---|---|---|
| Corrugated sheets | Separators with coarse emulsions and static mixers. | 40-1000 | 15-75<br>(35-180 $m^3/hr/m^2$) |
| Wire mesh, wire wool | Extraction columns, Distillation tower feeds, impeller mixers. | 20-300 | 7,5-45<br>(35-180 $m^3/hr/m^2$) |
| Co-knits of wire and polymer | Steam stripper bottoms, Caustic wash drums, High pressure drop mixing valves. | 10-200 | 7,5-45<br>(35-180 $m^3/hr/m^2$) |
| Glass mat, co-knits of wire and fiberglass | Haze from cooling in bulk liquid phase, Surfactants giving, Emulsions with very low interfacial tension. | 1-25 | 7,5-45<br>(35-180 $m^3/hr/m^2$) |

<u>Vapor-solid separator</u>

The most commonly encountered two phase vapor-solid separator in process industry is the decoking drum. A Decoking drum is provided for decoking of furnace tubes. Inlet stream to decoking drum may consist of steam, air and coke particles. Separation of coke particles from gases is essential to prevent coke particles being discharged to atmosphere or heater stack.

Separation of solid particles from vapor phase occurs under the influence of gravity. Forces which affect the rate of settling of solid particles are:

(i) gravity force

(ii) drag force due to relative motions

(iii) buoyancy force

Liquid-solid separator

Solid-liquid separation processes are generally based on either one or a combination of gravity settling, filtration, and centrifugation principles. In gravity settling separation, solid particles will settle out of a liquid phase if the gravitational force acting on the droplet or particle is greater than the drag force of the fluid flowing around the particle (sedimentation).

Mechanical separation by filtration involves passage of most of the fluid through a porous barrier which retains most of the solid particulates or liquid contained in the mixture. Centrifugal separation occurs by changing the direction of two phase stream sharply, thus the greater momentum will not allow the particles of heavier phase to turn as rapidly as the lighter fluid and separation occurs.

Some commonly used liquid-solid separators are filters, centrifuges, hydrocyclones, and gravity settlers.

**Three Phase Separator**

Vapor-liquid-liquid separator

Three phase separation is commonly applied when there are water, liquid hydrocarbon and hydrocarbon gases in the process stream. As with two phase design, three phase units can be either vertical or horizontal.

Vertical vessel is mainly applied when there is a large amount of vapor to be separated from a small amount of the light and heavy fluid (less than 10-20% by weight). Horizontal vessels are most efficient where large volumes of total fluid and large amounts of dissolved gas are present with the liquid. An example for vertical vessels is the compressor suction drums while good representative of horizontal vessel is the spent caustic deoiling drum.

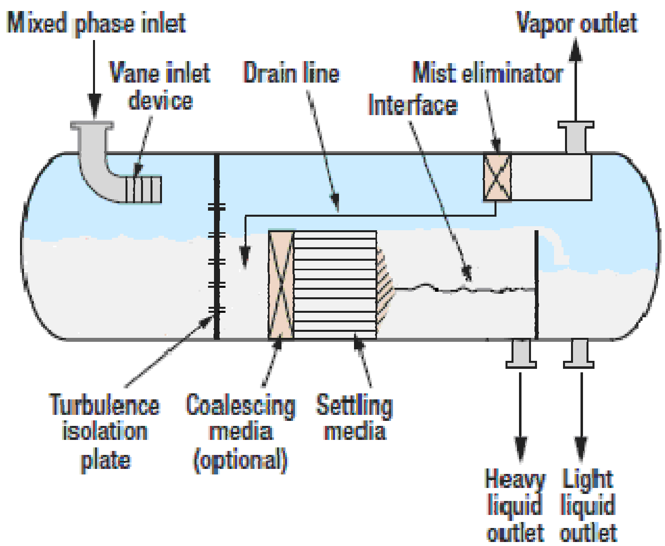


Figure 7. Horizontal 3-phase separator

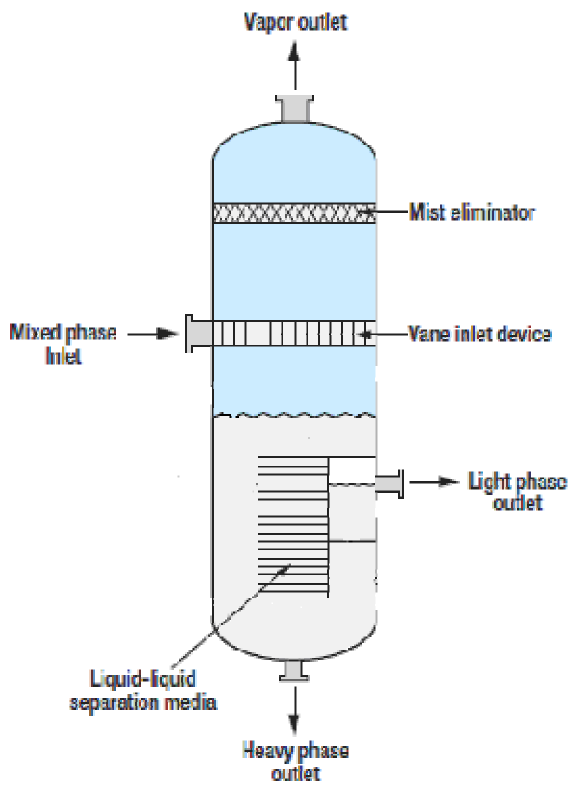


Figure 8. Vertical 3-phase separator

The three phase separation vessel commonly contains four major sections as listed below:

a. The primary separation section used to separate the main portion of free liquid in the inlet stream

b. The secondary or gravity section designed to utilize the force of gravity to enhance separation of entrained droplets.

c. The coalescing section utilizes a coalescer or mist extractor. Our normal application is using a knitted wire mesh pad on top of vessel.

d. The sump or liquid collection section acts as receiver for all liquid removed from gas in the primary, secondary, and coalescing section.

A vane-inlet device might be used in this separator to gradually reduce the inlet momentum and evenly distribute the gas phase across the vessel diameter. Such device can also act as the first-stage gas-liquid separation. In the gas-liquid portion of the vessel, a wire-mesh mist eliminator provides high separation efficiency.
For the liquid-liquid separation in the bottom of the drum, the first-stage is typically some type of enhanced-gravity separation media. If very high separation is required, adding a second “polishing” stage provides the ability to remove the last remnants of entrainment.

## General Design Consideration

### Vessel Orientation

As it is mentioned before, separator might be classified into vertical, horizontal, and spherical shape.

Each one of these shape has its own advantages. The vertical separator occupies less ground area and is easier to be cleaned. The horizontal separator can handle foaming crude oil better and is claimed to be more economical for handling large gas volumes. The spherical separator is easier to install and is more compact and adaptable for portable use.

However, design of spherical vessels is not included in this guideline. The choice between horizontal or vertical type of vessel primarily depends upon following process requirements:

- Relative liquid and vapor load
- Availability of plot area
- Economics
- Special considerations

Horizontal vessels are most economical for normal oil-water separation, particularly when there might be problems with emulsions, foam, or high gas-liquid ratios. Vertical vessels work most effectively in low gas-oil ratio (GOR) applications and where solids production is anticipated.

## Table 4. Comparison of different gravity separator types

| Parameters | Vertical | Horizontal | Spherical |
|---|---|---|---|
| Advantage | 1. Easier to clean<br>2. Saves space<br>3. Provides better surge control<br>4. Liquid level control is not critical<br>5. Less tendency for reevaporization of liquid into the gas phase due to the relatively greater vertical distance between liquid level and gas outlet | 1. Can handle much higher gas-oil ratio well streams because the design permits much higher gas velocities<br>2. Cheaper than the vertical separator<br>3. Easier and cheaper to ship and assemble<br>4. Requires less piping for field connections<br>5. Reduces turbulence and reduces foaming (thus, it can handle foaming crude)<br>6. Several separators may be stacked, minimizing space requirements | 1. Very inexpensive<br>2. Good for low or intermediate gas-oil ratio<br>3. Very compact and easy to ship and install<br>4. Better clean-out |
| Disadvantages | 1. It takes a longer diameter separator for a given gas capacity as compared to horizontal separator<br>2. More expensive to fabricate<br>3. Difficult and more expensive to ship (transport) | 1. Greater space requirements generally<br>2. Liquid level control more critical<br>3. Surge space is somewhat limited<br>4. Much harder to clean (hence a bad choice in any sand-producing area) | 1. Very limited liquid settling section and rather difficult to use for three phase separation<br>2. Liquid level control is very critical<br>3. Very limited surge space |
| Ideal use | Low to intermediate gas-oil ratio, and where relatively large slugs of liquid are expected | High gas-oil ratio crudes, foaming crudes, or for liquid-liquid separation. Good for a diverse range of situations | Intermediate or low gas-oil ratio, preferably two-phase separation |

## General Separator Design Consideration

Factors Affecting Separation

Characteristics of the flow stream will greatly affect the design and operation of a separator. The following factors must be determined before separator design:

- Gas and liquid flow rates (minimum, average, and peak)
- Operating and design pressures and temperatures
- Surging or slugging tendencies of the feed streams
- Physical properties of the fluids such as density and compressibility
- Designed degree of separation (e.g., removing 100% of particles greater than 10 microns)
- Presence of impurities (paraffin, sand, scale, etc.)
- Foaming tendencies of the crude oil
- Corrosive tendencies of the liquids or gas

Design Considerations

The following must be considered in designing separator vessel:

1. The volumes of the dished heads are negligible as compared with the volume of the cylinder
2. Unless specifically stated the length/diameter (L/D) is considered to be acceptable when it is between about 3/1 and 8/1. There is not a great change in cost over this ranger and other factors such as foundations, plant layout, and symmetry are significant.
3. For a vertical separator, the gas flows through the entire cross section of the upper part of the vessel. The feed enters the separator just above the vapor-liquid interface, which should be at least 2 ft from the bottom and at least 4 ft from the top of vessel. The interface does not have to be at the center of the vessel.
4. For a horizontal separator, the interface does not have to be at the centerline of the vessel. In some cases, a smaller-diameter vessel may be obtained by making the interface location off-center and a design variable. The feed enters at the end of

separator just above the vapor-liquid interface, which should be at least 10 in from the bottom and at least 16 in from the top of the vessel.

**General Separator Design Criteria**

Separator sizing must satisfy several criteria for good operation during the lifetime of the producing field:

1. Provide sufficient time to allow the immiscible gas, oil, and water phases to separate by gravity
2. Provide sufficient time to allow for the coalescence and breaking of emulsion droplets at the oil–water interface
3. Provide sufficient volume in the gas space to accommodate rises in the liquid level that result from the surge in the liquid flow rate
4. Provide for the removal of solids that settle to the bottom of the separator
5. Allow for variation in the flow rates of gas, oil, and water into the separator without adversely affecting separation efficiency.

**Instrumentation Requirements**

1. If a temperature indicator is required at the outlet, it should preferably be located on the top of outlet line.
2. A pressure gauge shall be installed on every vessel and normally located in vapor space. It should be clearly visible from grade or easily accessible platforms, i.e. installation on the tall vessel or column should be avoided.
3. Where exothermic processes are possible outside the normal temperature range, wide range thermocouples shall be installed at considered location where exothermic processes will result first in the part side of equipments so that, should an exothermic processes occurs, the maximum temperature can be monitored.

**Equipment Protection Requirements**

1. Pressure relief valves shall be connected to the protected equipment in the vapor space above any contained liquid or to piping connected to vapor space, downstream of the equipment blinding point. Pressure Safety Valve (PSV) should be installed to protect vessel from over pressure. Set point at PSV shall no higher than maximum allowable working pressure of the vessel. PSV line is vented to atmosphere at safe height or location from operator.

2. High Pressure Sensor (PSH) should be installed as an alarm initiation pressure to give sufficient time for operator to do safety operation and also use High High Pressure Sensor (PSHH) to shut off inflow fluid to vessel if operator fails to handle over pressure. If fluids inlet to the vessel is coming from a well, PSH and PSHH should always be installed at vessel considering increase pressure due to change in reservoir conditions, artificial lift, work-over activities, etc.

3. To avoid vacuum condition in the vessel, Low Pressure Sensor (PSL) as an alarm initiation pressure to give sufficient time for operator to do safety operation and also use Low Low Pressure Sensor (PSLL) to shut off inflow fluid to vessel if operator fails to handle vacuum pressure. PSL and PSLL should always be considered to be installed when possible leaks large enough to reduce pressure occur.

4. Height of Liquid level should be controlled with control device both in top side of maximum liquid level (surge volume) and bottom side. In top side, High Level Sensor (LSH) to give sufficient time for operator to do safety operation and also use High High Level Sensor (PSHH) to shut off inflow fluid to vessel if operator fails to handle liquid over flow level.

5. In bottom side, Low Level Sensor (LSL) as an alarm initiation for operator should be used and use Low Low Level Sensor (LSLL) to shut off inflow fluid to vessel if operator fails to close liquid outlet at the bottom vessel to avoid gas blowby.

6. If the vessel is heated, a High Temperature Sensor (TSH) should be installed to shut off the heat source when process fluid temperature becomes excessive.

7. Consider to install a check valve as flow safety device (FSV) at outlet lines both gas outlet line and liquid outlet line(s) of pressure vessel if significant fluid volumes could back flow from downstream equipment is possible.

8. For vessel fitted with demister (i.e. wire mesh, vane pack), a pressure relief valve downstream of demister is allowed if the velocity of the largest relief flow is not greater than 3 times that of the design operating flow. The relief connection shall be upstream of demister for larger relief flows. It should be noted that blockage can not occur as result of fouling, solidification, collapse of internals, etc. Otherwise, the relief connection shall be located upstream of the potential restriction.

9. The inlet piping between protected equipment and inlet of relief valve should be designed so that the total pressure loss does not exceed 3% of the valve set pressure. The pressure loss should be calculated using the maximum rated capacity of the pressure relief valve. Excessive pressure loss will cause rapid opening and closing the valve, or chatter. The nominal size of the inlet piping must be the same as or larger than the nominal size of the valve inlet flange. The inlet piping of pressure relief valve shall be self draining back into the process.

10. All process equipment containing under normal operating condition at least 2 tons of LPG (butane or volatile liquid) shall be provided with remotely operated depressuring valves. High rate depressuring of plant facilities is applied during an emergency.

11. For 2 phase separator of gas-free water separation, the separators may have internal coating to protect the shell made by carbon steel from water corrosion.

## DEFINITIONS

**Accumulators-** These are storage tanks following distillation column condensers. For partial condensers, this flow may be a mixture of vapor and liquid. The outlet flow may be regulated by a level controller in order to avoid the tank either flooding (liquid out the top) or going dry (vapor out the bottom).

**Coalescer-** A mechanical process vessel with wettable, high-surface area packing on which liquid droplets consolidate for gravity separation from a second phase (for example gas or immiscible liquid).

**Control Volume-** A certain liquid volume necessary for control purposes and for maintaining the velocity limit requirement for degassing and to counter foam in separators.

**Conventional Gas-Liquid Separator-** Vertical or horizontal separators in which gas and liquid are separated by means of gravity settling with or without a mist eliminating device.

**Critical Diameter-** Diameter of particles larger than which will be eliminated in a sedimentation centrifuge.

**Demister Mist Extractor-** A device installed in the top of scrubbers, separators, tray or packed vessels, etc. to remove liquid droplets entrained in a flowing gas stream.

**Disengaging Height-** The height provided between bottom of the wire-mesh pad and liquid level of a vapor-liquid separator.

**Fabric Filter-** Commonly termed "bag filters" or "baghouses", are collectors in which dust is removed from the gas stream by passing the dust-laden gas through a fabric of some type.

**Filter-** A piece of unit operation equipment by which filtration is performed.

**Filter Medium-** The "filter medium" or "septum" is the barrier that lets the liquid pass while retaining most of the solids; it may be a screen, cloth, paper, or bed of solids.

**Filtrate-** The liquid that passes through the filter medium is called the filtrate.

**Flash drums-** Vessels into which flow a mixture of liquid and vapor. The goal is to separate the vapor and liquid. For design calculations it is normally assumed that the vapor and liquid are in equilibrium with one another and that the vessel is adiabatic (no heat lost or gained). One must simultaneously satisfy a material balance, a heat balance, and equilibrium.

**Flash Tank-** A vessel used to separate the gas evolved from liquid flashed from a higher pressure to a lower pressure.

**Hold-Up Time-** A time period during which the amount of liquid separated in a gas-liquid separator is actually in the vessel for the purpose of control or vapor separation.

**Knock-Out-** A separator used for a bulk separation of gas and liquid.

**Line Drip-** A device typically used in pipelines with very high gas-to-liquid ratios to remove only free liquid from a gas stream,and not necessarily all the liquid.

**Mesh-** The "mesh count" (usually called "mesh"), is effectively the number of openings of a woven wire filter per 25 mm, measured linearly from the center of one wire to another 25 mm from it.

**Open Area-** A percentage of the whole area of a woven wire filter.

**Overflow-** The stream being discharged out of the top of a hydrocyclone, through a protruding pipe, is called "overflow". This stream consists of bulk of feed liquid together with the very fine solids.

**Scrubber-** A type of separator which has been designed to handle flow streams with unusually high gas-to-liquid ratios.

**Slug Catcher-** A particular separator design able to absorb sustained in-flow of large liquid volumes at irregular intervals.

**Surge tanks-** These are storage tanks between units, and can serve a variety of purposes. They can dampen fluctuations in flow rate, composition or temperature. They can allow one unit to be shut down for maintenance without shutting down the entire plant.

**Target Efficiency-** The fraction of particles or droplets in the entraining fluid of a separator, moving past an object in the fluid, which impinge on the object.

**Terminal Velocity or Drop-Out Velocity-** The velocity at which a particle or droplet will fall under the action of gravity, when drag force just balances gravitational force and the particle (or droplet) continues to fall at constant velocity.

**Underflow-** The stream containing the remaining liquid and the coarser solids, which is discharged through a circular opening at the apex of the core of a hydrocyclone is referred to as "underflow".

**Vapor Space-** The volume of a vapor liquid separator above the liquid level.