6. Phase Separation

- selecting gas-liquid separation technologies should be made based on the **droplet size, concentration, and whether the liquid has waxing or fouling tendencies**.
- Three principles used to achieve physical separation of gas and liquids or solids are **momentum, gravity settling, and coalescing**.
- Any separator may employ one or more of these principles; however, the fluid phases must be immiscible and have different densities for separation to occur.
- **Momentum force** is utilized by changing the direction of flow and is usually employed for bulk separation of the fluid phases.
- **The gravitational force** is utilized by reducing velocity so that the liquid droplets can settle out in the space provided.
- **Gravity segregation** is the main force that accomplishes the separation, which means the heaviest fluid settles to the bottom and the lightest fluid rises to the top.

6.1. Gravity Separators

- Gravity separators are pressure vessels that separate a mixed-phase stream into gas and liquid phases that are relatively free of each other.
- In a gravity separator, gravitational forces control separation, and the efficiency of the gas-liquid separation is increased by lowering the gas velocity.
- gravity separators are rarely designed to remove droplets smaller than 250 microns because of the large vessel size required to achieve settling.
- Gravity separators are often classified by their geometrical configuration **(vertical, horizontal)** and by their function **(two-phase/three-phase separator)**. In other words, gravity separators are classified as "two-phase" if they separate gas from the total liquid stream and "three-phase" if they also separate the liquid stream in to its crude oil and water-rich phases.
- Additionally, separators can be categorized according to their operating pressure. **Low-pressure** units handle pressures of 10-180 psi. **Medium-pressure** separators

operate from 230 to 700 psi. **High-pressure** units handle pressures of 975-1500 psi.

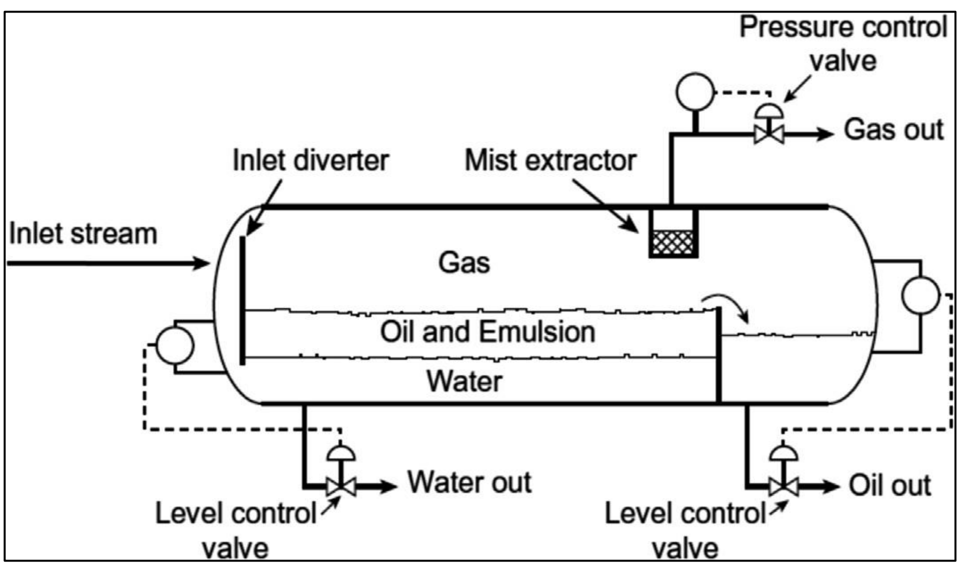
- Separators are sometimes called "**scrubbers**" when the ratio of gas rate to liquid rate is very high.

6.1.1. General Description

All gravity separators normally have the following components or features:

- A primary gas-liquid separation section with an inlet divertor to remove the bulk of the liquid from the gas.
- A gravity settling section providing adequate retention time so that proper settling may take place.
- A mist extractor at the gas outlet to capture entrained droplets or those too small to settle by gravity.
- Proper pressure and liquid level controls.

1. **Three-phase horizontal separator:** Fig. below is a typical scheme of a three-phase horizontal separator.

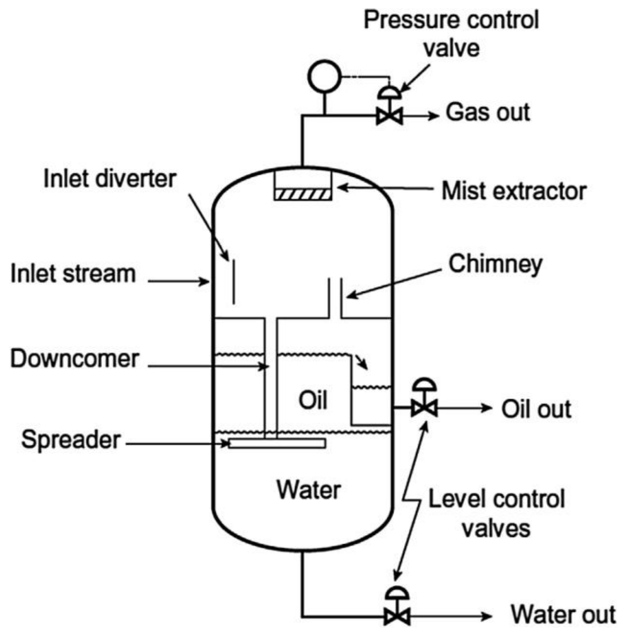


A typical scheme of horizontal three-phase separator.

- The fluid enters the separator and hits an inlet diverter. This sudden change in momentum generates the initial bulk separation of liquid and gas. In most designs, the inlet diverter contains a downcomer that directs the liquid flow below the oil-water interface.
- The liquid collecting section of the vessel provides sufficient time so that the oil and emulsion form a layer or “oil pad” at the top.
- The free water settles to the bottom. The produced water flows from a nozzle in the vessel located upstream of the oil weir.
- An interface level controller senses the height of the oil-water interface. The controller sends a signal to the water dump valve, thus allowing the correct amount of water to leave the vessel so that the oil-water interface is maintained at the design height.
- The gas flows horizontally and outs through a **mist extractor** (normally known as a demisting device) to a pressure control valve that maintains constant vessel pressure.
- The level of the gas-oil interface can vary from half the diameter to 75% of the diameter depending on the relative importance of liquid-gas separation, and what purpose the separator has.

2. Vertical three-phase separator

- Fig. below shows a typical configuration for a vertical three-phase separator.
- In the vertical separator, the flow enters the vessel through the side and the inlet diverter separates the bulk of the gas.
- The gas moves upward, usually passing through a **mist extractor** to remove suspended mist, and then the dry gas flows out.
- A downcomer is required to transmit the liquid collected through the oil-gas interface so as not to disturb the oil skimming action taking place.
- A **chimney** is needed to equalize gas pressure between the lower section and the gas section.



A typical scheme of vertical three-phase separator.

- ❖ The spreader or downcomer outlet is located at the oil-water interface. From this point, as the oil rises any free water trapped within the oil phase separates out.
- ❖ The water droplets flow countercurrent to the oil. Similarly, the water flows downward and oil droplets trapped in the water phase tend to rise countercurrent to the water flow.
- ❖ The principles of operation (such as oil-water interface level controlling) of three-phase vertical separators are the same as three-phase horizontal separators those described above.
- ❖ Essentially, the only difference is that horizontal separators have separation acting tangentially to flow, whereas vertical separators have separation acting parallel to flow.

6.1.2. Separators Selection

Each type of separators is most commonly used in the following conditions:

Horizontal Separators	Vertical Separators
• Large volumes of gas and/or liquids • High-to-medium gas-oil ratio (GOR) streams • Foaming crudes • Three-phase separation	• Small flow rates of gas and/or liquids • Very high GOR streams or when the total gas volumes are low. • Plot space is limited. • Ease of level control is desired.

The advantages and disadvantages of horizontal separators are:

Advantages	Disadvantages
• Require smaller diameter for similar gas capacity as compared with vertical vessels. • No counter flow (gas flow does not oppose drainage of mist extractor). • Large liquid surface area for foam dispersion generally reduces turbulence. • Larger surge volume capacity.	• Only part of shell available for passage of gas. • Occupies more space unless "stack" mounted. • Liquid-level control is more critical. • More difficult to clean produced sand, mud, wax, paraffin, etc.

The advantages and disadvantages of vertical separators are:

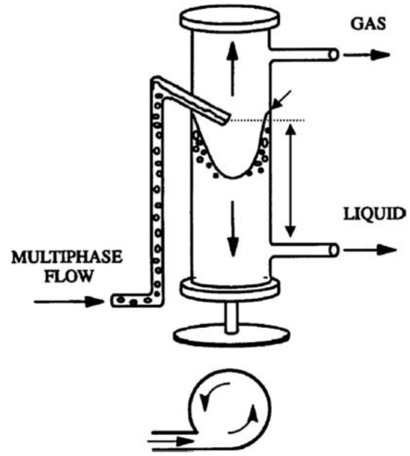
Advantages	Disadvantages
• Liquid-level control is not so critical. • Have good bottom-drain and clean-out facilities. • Can handle more sand, mud, paraffin, wax without plugging. • Lower tendency for re-entrainment. • Has full diameter for gas flow at top and oil flow at bottom. • Occupies smaller plot area.	• Require larger diameter for a given gas capacity, therefore, most competitive for very low GOR or very high GOR or scrubber applications. • It is not recommended when there is a large slug potential. • More difficult to reach and service top-mounted instruments and safety devices.

6.1.3. Multistage Separation

- To achieve good separation between the gas and liquid phases and maximizing the hydrocarbon liquid recovery, it is necessary to use several separation stages at decreasing pressures in which the well stream is passed through two or more separators that are arranged in series.
- The operating pressures are sequentially reduced, hence the highest pressure is found at the first separator and the lowest pressure at the final separator.
- In practice, the number of stages normally ranges between 2 and 4, which depends on the GOR and the well stream pressure.
- Two-stage separation is usually used for low GOR and low well stream pressure, three-stage separation is used for medium to high GOR and intermediate inlet pressure, and four-stage separation is used for high GOR and high pressure well stream.
- To recover the gases fractions produced in the separators operating at medium pressure and at low pressure, it is necessary to recompress them to the pressure of high-pressure separator.
- It should be noted that the main objective of stage separation is to provide maximum stabilization to the resultant phases (gas and liquid) leaving the final separator,

6.2. Centrifugal Separators

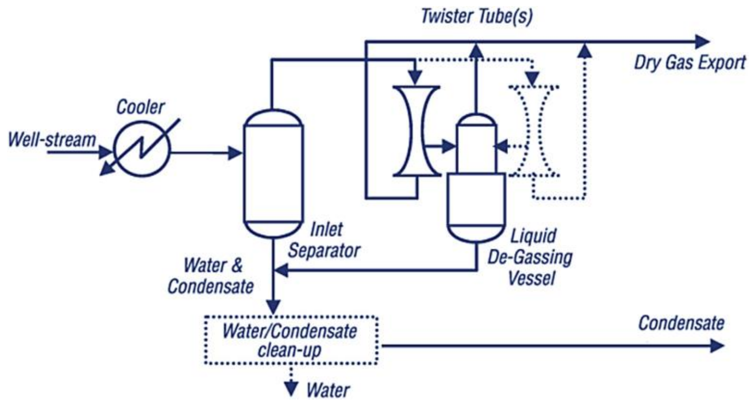
- In centrifugal or cyclone separators, centrifugal forces act on a droplet at a force several times greater than gravity, as it enters a cylindrical separator below.
- This centrifugal force can range from 5 times gravity in large, low velocity unit to 2000 times gravity in small, high-pressure units.
- Generally, centrifugal separators are used for removing droplets greater than 100 μm in diameter.
- The compact dimensions, smaller footprint, and lower weight of the centrifugal separators have a potential for cost savings to the industry, especially in offshore applications.



Gas-liquid cylindrical cyclone configuration

6.3. Twister supersonic separator

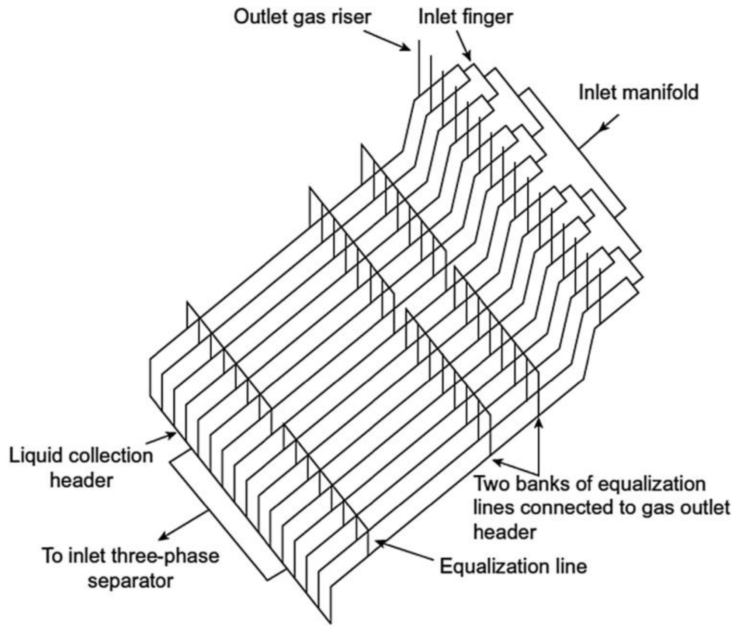
- The Twister supersonic separator is a unique combination of the expansion, cyclonic gas-liquid separation, and recompression process steps in a compact, static, tubular device to condense and separate water and heavy hydrocarbons from natural gas.
- Twister achieves a temperature drop by transforming pressure to kinetic energy (i.e., supersonic velocity). The tube is the heart of the Twister system that combines adiabatic cooling, in which no heat enters or leaves the system.
- Twister is a low-temperature separation process, for which performance can be optimized by inlet cooling.
- The residence time inside the Twister supersonic separator is only milliseconds, allowing hydrates no time to form and avoiding the requirement for hydrate inhibition chemicals.
- The simplicity and reliability of a static device, with no rotating parts which operates without chemicals, ensures a simple and safe facility with a high availability, suitable for unmanned operation in harsh and/or offshore environments.



Process flow diagram for a typical Twister system.

6.4. Slug catchers

- Slug catchers are used at the terminus of large gas-condensate transmission pipelines to catch large slugs of liquid in pipelines, to hold these slugs temporarily, and then to allow them to follow into downstream equipment and facilities at a rate at which the liquid can be properly handled.
- In fact, the slug catcher provides temporary storage for any surges (slugs) in liquid flows and roughly separates the gas from the liquids.
- Slug catchers may be either of the vessel or of the manifold pipe type.
- Avessel-type slug catcher is essentially a **knockout vessel**.
- A pipe-type slug catcher consists of several long pieces of pipe (fingers), which together form the buffer volume to store the largest slugs expected from the upstream system.
- A schematic of a pipe-type slug catcher is shown in Fig. below.

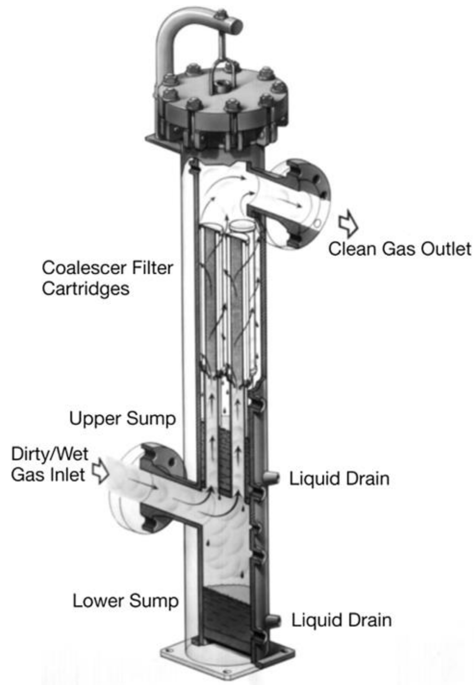


Three-dimensional rendering of finger-type slug catcher.

6.5. High-efficiency liquid-gas coalescers

- ❖ Aerosols in gas streams can often be less than 5 microns in size and require the use of special separation equipment.
- ❖ High-efficiency liquid-gas coalescers have been applied effectively for the removal of fine aerosols.
- ❖ Coalescers are typically constructed as cartridges that use pleated glass fiber media supported by a metal core.
- ❖ The coalescer cartridges are then placed in a housing that controls the inlet-outlet gas velocities to ensure good separation and prevent any reentrainment of liquids.
- ❖ A vertical high-efficiency liquid-gas coalescer system is shown in Fig. below.
- ❖ The inlet gas with liquid aerosol contamination first enters at the bottom of the housing into a first stage knockout section. Here any slugs or larger size droplets (approximately >300 mm) are removed by gravitational settling.
- ❖ The gas then travels upward through a tube sheet and flows radially from the inside of the cartridges through the coalescer medium to the annulus.

- ❖ Once the coalesced droplets are formed, they immediately drain vertically downward in the coalescer medium pack.



High-efficiency vertical liquid-gas coalescer system.