Republic of Iraq

Ministry of Higher Education

and Scientific Research

Al-Mustaqbal University College

Chemical Engineering and Petroleum Industries

Department

Subject: Oil and Gas Field Processing

3rd Class

Lecture 3

Gas–Oil Separation

The first step in processing the well stream is to separate the crude oil, natural gas, and water phases into separate streams. The purpose of the separators is to split the flow into desirable fractions.

A separator is a pressure vessel used to separate well fluids produced from oil and gas wells into gaseous and liquid components in the oilfield. Gas–oil separators can be horizontal, vertical, or spherical (Figure 3-1, 3-2, 3-3).

In general, well effluents flowing from producing wells come out in two phases: vapor and liquid under a relatively high pressure. The fluid emerges as a mixture of crude oil and gas that is partly free and partly in solution. Fluid pressure should be lowered and its velocity should be reduced in order to separate the oil and obtain it in a stable form. This is usually done by admitting the well fluid into a gas–oil separator plant (GOSP) through which the pressure of the gas–oil mixture is successively reduced to atmospheric pressure in a few stages. Upon decreasing the pressure in the GOSP, some of the lighter and more valuable hydrocarbon components that belong to oil will be unavoidably lost along with the gas into the vapor phase.

Oil-field separators can be classified into two types **based on the number of phases to separate**:

1. Two-phase separators, which are used to separate gas from oil in oil fields, or gas from water for gas fields.

2. Three-phase separators, which are used to separate the gas from the liquid phase, and water from oil.

Crude oil as produced at the wellhead varies considerably from field to field due not only to its physical characteristics but also to the amount of gas and salt water it contains. In some fields, **no salt water will flow into the well from the reservoir along with the produced oil**, where it is only necessary to separate the gas from the oil (i.e., two-phase separation). When, on the other hand, salt water is produced with the oil, it is then essential to use a three-phase separator.

Hydrocarbon mixtures contain essentially three main groups of hydrocarbon:

1. Light group, which consists of CH_4 (methane) and C_2H_6 (ethane).

2. Intermediate group, which consists of two subgroups—the propane/butane (C_3H_8/C_4H_{10}) group and the pentane/hexane (C_5H_{12}/C_6H_{14}) group.

3. Heavy group, which is the bulk of crude oil and is identified as C_7H_{16}.

In carrying out the gas–oil separation process, the main objective is to try to achieve the following:

• Separate the C_1 and C_2 light gases from oil

• Maximize the recovery of heavy components of the intermediate group in crude oil

• Save the heavy group components in liquid product

Functional Components of a Gas–Oil Separator

The main sections of a separator: Inlet diverter section, gravity settling section, mist extractor section, and liquid collection section.

• Section A—Initial bulk separation of oil and gas takes place in this section. The entering fluid mixture hits the inlet diverter. This causes a sudden change in momentum (velocity and direction) and, due to the gravity difference, results in bulk separation of the gas from the oil. The gas then flows through the top part of the separator and the oil through the lower part.

• Section B—Gravity settling and separation is accomplished in this section of the separator. Oil droplets settle and separate from the gas because of the substantial reduction in gas velocity and the density difference.

• Section C—Known as the mist extraction section, it is capable of removing the very fine oil droplets that did not settle in the gravity settling section from the gas stream. The function of the mist extractor is to remove the very fine liquid droplets from the gas before it exits the separator. Several types of mist extractors are available, including wire-mesh, vane and centrifugal. The liquid droplets that did not separate in the gravity settling section of the separator coalesce on the surface of the matted wire. As the droplets size grows, they fall down into the liquid phase.

• Section D—This is known as the liquid sump or liquid collection section. Its main function is collecting the oil and retaining it for a sufficient time to reach equilibrium with the gas before it is discharged from the separator.

Oil is about eight times as dense as the gas. This could be a sufficient driving force for the liquid particles to separate and settle down. Crude oil leaves at the bottom through a level-control or dump valve. The gas leaves the vessel at the top, passing through a mist extractor to remove the small liquid droplets in the gas.

The degree of separation between gas and liquid inside the separator depends on the following factors: **separator operating pressure**, **the residence time of the fluid mixture**, and **the type of flow of the fluid** (turbulent flow allows more gas bubbles to escape than laminar flow).

Two-Phase Gas-Oil Separators

Figure 3-1 is a cutaway of a horizontal two-phase separator. The fluid enters the separator and hits an inlet diverter, causing a sudden change in momentum. The initial gross separation of liquid and vapor occurs at the inlet diverter. The force of gravity causes the liquid droplets to fall out of the gas stream to the bottom of the vessel, where it is collected. The liquid collection section provides the retention time required to let entrained gas evolve out of the oil and rise to the vapor space and reach a state of "equilibrium.". The liquid leaves the vessel through the liquid dump valve.

Gas and oil mist flow over the inlet diverter and then horizontally through the gravity settling section above the liquid. As the gas flows through this section, some droplets of liquid that were entrained in the gas and not separated by the inlet diverter are separated out by gravity and fall to the gas-liquid interface.

Some of the drops are of such a small diameter that they are not easily separated in the gravity settling section. Before the gas leaves the vessel, it passes through a coalescing section or mist extractor. This section uses elements of vanes, wire mesh, or plates to provide a large amount of surface area used to coalesce and remove the very small droplets of liquid in one final separation before the gas leaves the vessel. Horizontal separators are smaller and thus less expensive than a vertical separator for a given gas and liquid flow rate. Horizontal separators are commonly used in flow streams with high gas-liquid ratios and foaming crude.

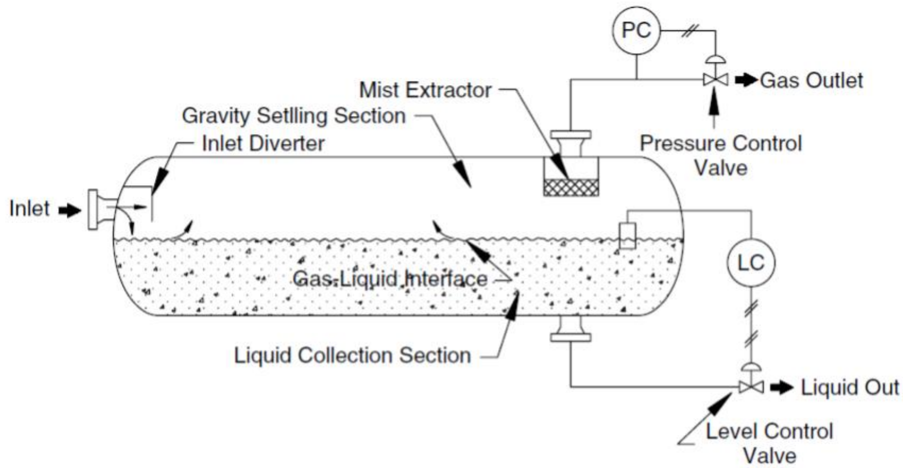


Figure 3-1. Two-Phase Horizontal separator schematic

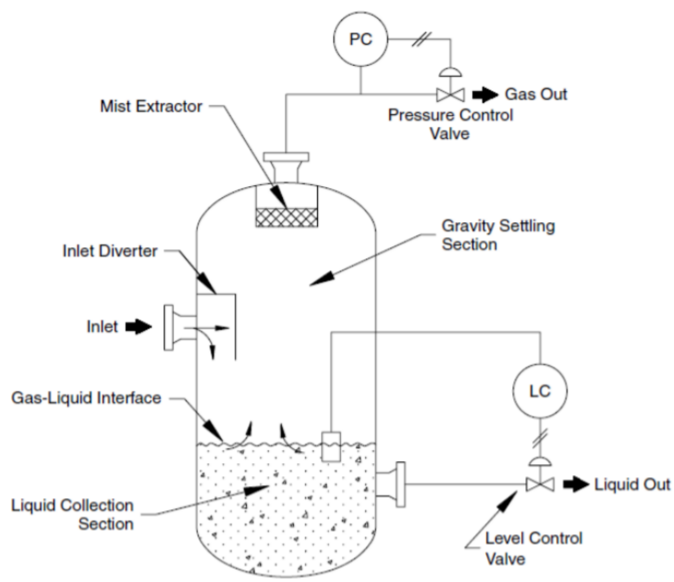


Figure 3-2. Two-Phase Vertical separator schematic.

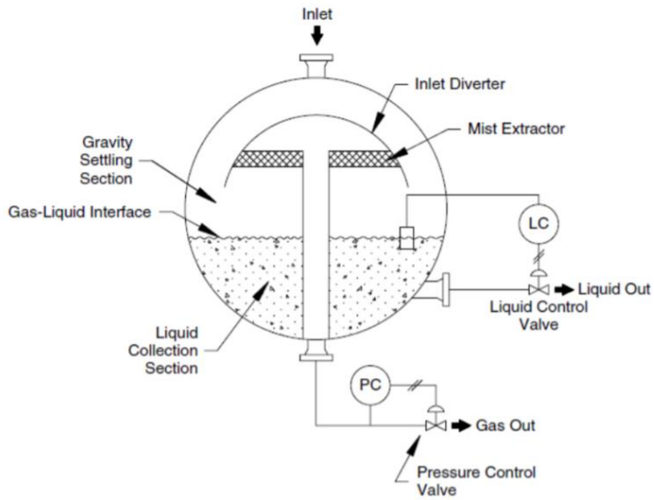
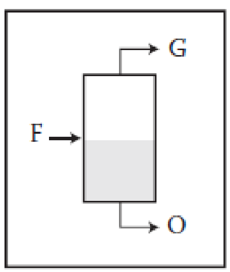
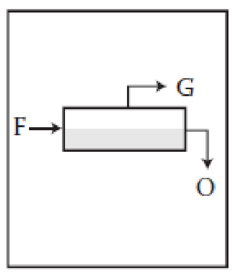
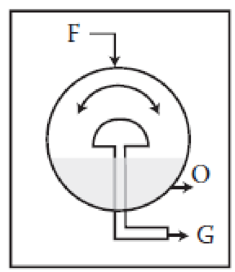


Figure 3-3. Two-Phase Spherical separator schematic.

Comparison among Different Configurations of Gas–Oil Separators

Function	Vertical	Horizontal	Spherical
Usage	For low G/O	For high G/O	For small leases operating at moderate pressure
Location of inlet and outlet stream			
Capacity or efficiency	Large fluid capacity	Large gas capacity (handles high GOP)	Capacity rated less (low efficiency)
Maintenance and inspection	Very difficult	Accessible	Average
Cost per unit capacity	Average	The cheapest	Most expensive
Installation	Most difficult	Average	Easy to install

Three-Phase Oil–Water–Gas Separators

The term separator in oil field terminology designates a pressure vessel used for separating well fluids produced from oil and gas wells into gaseous and liquid components. Separators work on the principle that the three components have different densities, which allows them to stratify when moving slowly with gas on top, water on the bottom, and oil in the middle. Any solids such as sand will also settle in the bottom of the separator.

Generally, water produced with the oil exists partly as free water and partly as water-in-oil emulsion. Free water produced with the oil is defined as the water that will settle and separate from the oil by gravity.

Along with the water and oil, gas will always be present and, therefore, must be separated from the liquid. The volume of gas depends largely on the producing and separation conditions. When the volume of gas is relatively small compared to the volume of liquid, the method used to separate free water, oil, and gas is called a free-water knockout. In such a case, the separation of the water from oil will govern the design of the vessel. When there is a large volume of gas to be separated from the liquid (oil and water), the vessel is called a three-phase separator and either the gas capacity requirements or the water–oil separation constraints may govern the vessel design.

Free-water knockout and three-phase separators are basically similar in shape and components. Further, the same design concepts and procedures are used for both types of vessel. Therefore, the term three-phase separator will be used for both types of vessel throughout this section.

Three-phase separators may be either horizontal or vertical pressure vessels similar to the two-phase separators described above. However, three-phase separators will have additional control devices and may have additional internal components.

Three-phase separators differ from two-phase separators in that the liquid collection section of the three-phase separator handles two immiscible liquids (oil and water) rather than one. This section should, therefore, be designed to separate the two liquids to provide means for controlling the level of each liquid and to provide separate outlets for each liquid (Figure 3-4) .

The operation of the separator is, in general, similar to that of the two-phase separator. The produced fluid stream coming either directly from the producing wells or from a free-water knockout vessel enters the separator and hits the inlet diverter, where the initial bulk separation of the gas and liquid takes place due to the change in momentum and difference in fluid densities. The gas flows horizontally through the gravity settling section (the top part of the separator) where the entrained liquid droplets, down to a certain minimum size (normally 100 μm), are separated by gravity. The gas then flows through the mist extractor, where smaller entrained liquid droplets are separated, and out of the separator through the pressure control valve, which controls the operating pressure of the separator and maintains it at a constant value.

The bulk of liquid, separated at the inlet diverter, flows downward. The liquid collection section should have sufficient volume to allow enough time for the separation of the oil and emulsion from the water. The oil and emulsion layer forming on top of the water is called the oil pad. The oil and emulsion flow over the weir and collect in a separate compartment, where its level is controlled by a level controller that operates the oil outlet valve.

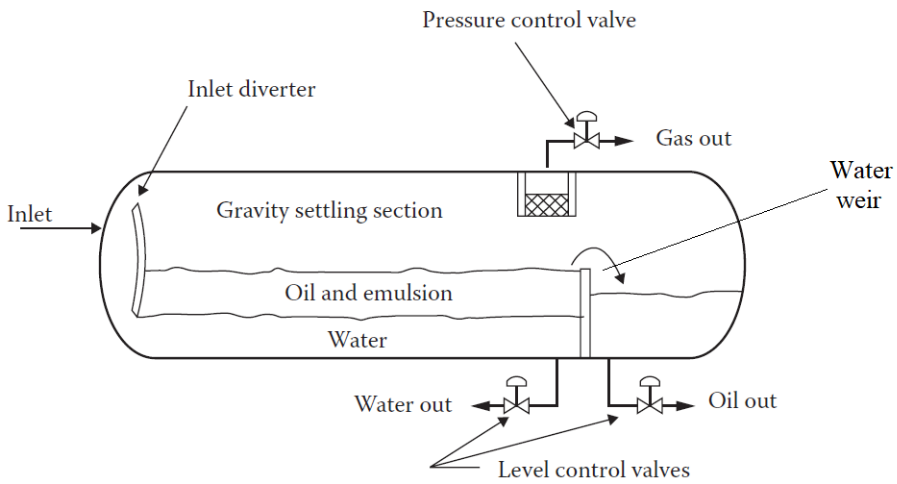


Figure 3-4. Three-phase separator horizontal.