Tikrit University

The College of Petroleum Processes Engineering

Petroleum Systems Control Engineering

Department

Petroleum Refining Processes

Fourth Class

Lecture 3

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Well Fluid Compositions:

Fluid flow from a well can include gas, free water, condensable vapors (water or hydrocarbon), crude oil, and solid debris (basic sediment). The proportion of each component varies in different well streams. When water is produced with crude oil, it is mixed in either or both of the following forms:

1. **Free Water/Produced Water**: Water mixed with the oil but will separate easily into a clear layer when the mixture is allowed enough time to settle.
2. **Emulsion**: Water can also be mixed with the oil in the form of very small droplets of water coated with oil. A mixture like this is called emulsion. Water in this case cannot be easily separated from oil and need to undergo **demulsifications process** in order to remove the water content in crude. As for the gas, it can be found in the well as (The associated gas):

1. **Solution Gas**: Gas dissolved in the well fluids under the effect of pressure of the reservoir. As the fluids flow from the reservoir into the well and up to the surface, the pressure of the fluid decreases. The capacity of the liquid to hold gas in solution also decreases and gas starts to separate out of the oil.
2. **Free Gas (gas-cap-gas)**: Gas that is not held in the oil under reservoir conditions, lying above the oil reservoir.
3. **Reservoir rock:** They are rocks found inside the well that have permeability and emit gases. is found in shale, sandstone, sandy carbonates, limestones. The methane produced from these reservoirs is associated with oil.

Associated gas (also called wet gas): is usually leaner in methane and richer in higher molecular weight hydrocarbons (gas liquids), containing high proportions of natural gas liquids (NGLs) that have a higher boiling point than methane.

Associated Gas: Total gas produced with the oil in a crude oil well. This type of gas is separated in the three phase gravity separator and will under further treatment to be converted into Liquefied Petroleum Gas (LPG product), sales gas to petrochemical industries or used as a fuel gas for burner/heater at the production facility.

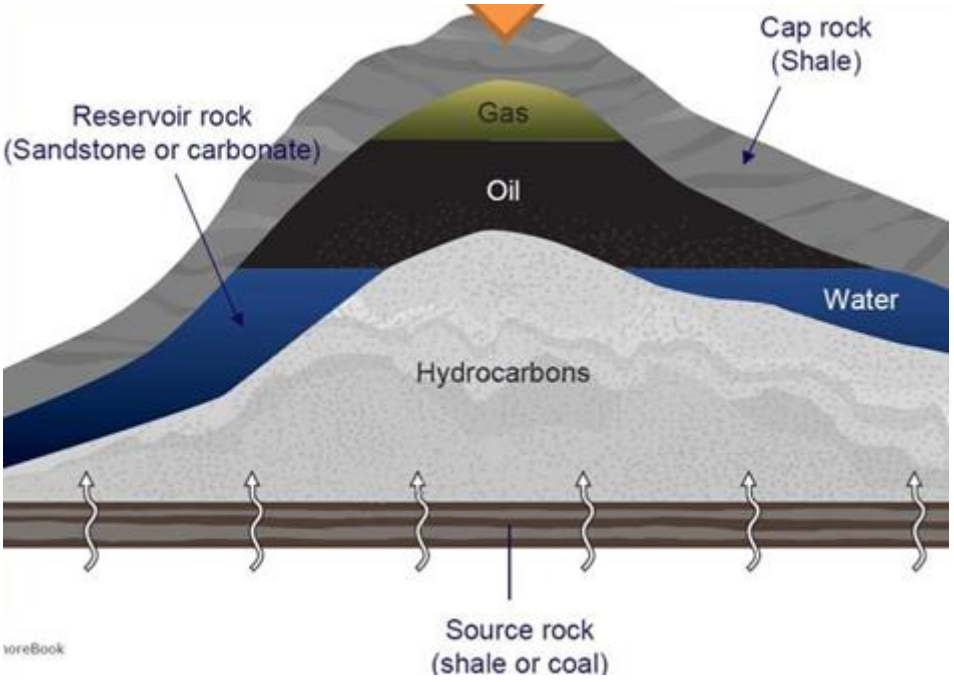

Figure 1. Sources of associated gas in the well.

Separation Gas & Liquid:

- The well-stream may consist of crude oil, gas, condensates, water and various contaminants.
- The purpose of a separator is to split the flow into desirable fractions.
- Primary separation of produced water from gas and oil is carried out in production separator.
- Separators work on the principle of gravity separation.

The following are the types of separators generally used in the oil industry:

- Two Phase Separator; A two phase separator is used to separate well fluids into gas and liquid mixtures.
- Three Phase Separator; This type of separator is used when the expected outlet streams are gas, oil/condensate, and water.

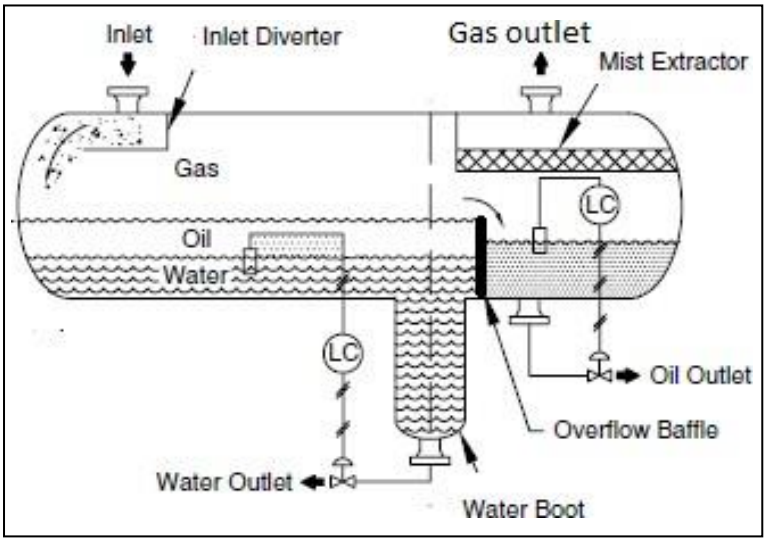

Figure 2. Typical Three Phase Separator (horizontal)

A separator can be either horizontal or vertical configuration

- Horizontal separator; Horizontal separator is preferred for low GOR well fluids and three phase separation.

Table below shows the advantages and disadvantages of horizontal separators:

Advantages	Disadvantages
Provide sufficient residence time for liquid-liquid separation	Only part of shell available for passage of gas
Large liquid surface area for foam dispersion generally reduces turbulence	Larger foot print / plot area
Large surge volume capacity	Liquid level control is more critical
Lend themselves to skid mounting and shipping	More difficult to clean produced sand, mud, wax, paraffin. etc.

- Vertical separator; Vertical separator is preferred for high GOR well fluids and three phase separation.

Table below shows the advantages and disadvantages of vertical separators:

Advantages	Disadvantages
Have full diameter for gas flow at top and oil flow at bottom	Not suitable for bulk liquid-liquid separation
Occupy smaller plot area	Occupy more vertical spacing between decks in Offshore
Liquid level control is not so critical	More difficult to skid mount and ship
Have good bottom drain and clean out facilities. Can handle more sand, mud, paraffin, wax, etc.	More difficult to reach and service top-mounted instruments and safety devices

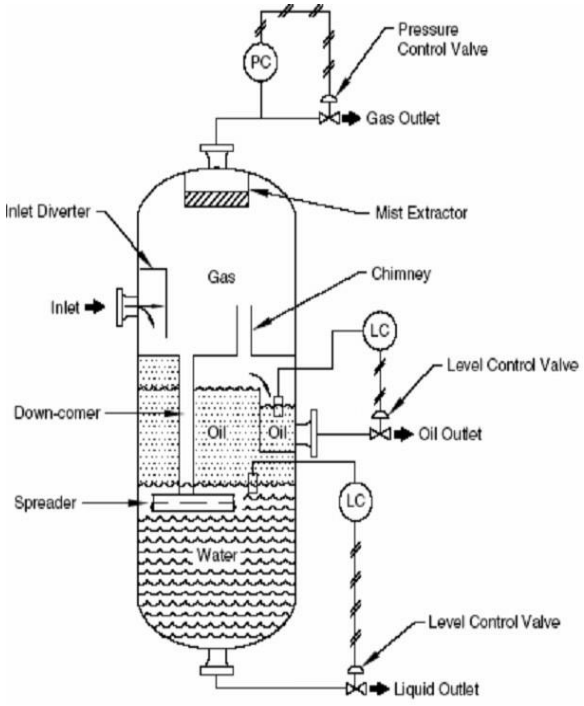

Figure 3. Typical Three Phase Separator (vertical)

Crude Oil Stabilization:

Separation is a process to separate the gas from the liquid and the water from the oil. This is usually done in a separator which is an unfired pressure vessel. The well stream flows into the separator and allow the gas, oil and water to separate because of the gravity. During the separations: crude oil stabilization process, gas is flashed from the liquids and 'free water' is separated from the oil. These steps remove enough light hydrocarbons to produce a stable crude oil with the volatility (vapor pressure) to meet sales criteria. The gas that is separated must be compressed and treated for sales, while the free water produced will undergo further hydrocarbon recovery process as to reduce the oil proportion below 10 mg/L before being discharged as water effluents to the sea.

Crude oil stabilization processes:

- Dissolved gas in the crude oil must be removed to meet pipeline, storage, or tanker RVP specification.
- Removal of the dissolved natural gas components is called oil stabilization.
- Crude oil can be stabilized by passing it through multiple separators in series where the volatile components will vaporize.
- A stabilization column might replace the simple flash-separation stages to achieve the required RVP, but these columns are rarely found offshore.

Stabilization of the crude oil often requires:

Heat to be added or removed at certain points in the processing train. Crude heating may be required for:

- Emulsion breaking and improved separation of oil and produced water.
- Adjustments of final product vapor pressure and H_2S content.

Number of Separation Stage:

- The well fluid pressure is often reduced in several stages of separation.
- If the reservoir fluid can flow adequately against a wellhead pressure, separation in more than one stage will generally offer an economic advantage.
- The purpose of multi stage separation is to achieve maximum hydrocarbon liquid recovery, to get the liquid stabilized, and minimize compression power required for the gas stream.
- Multi stage separation of oil and gas involves a series of separators operating at sequentially reduced pressures, with liquid flowing from first separator to the next lower pressure separator.
- The optimum number of separation stages varies with Flowing Wellhead Pressure (FWHP), reservoir composition, off-gas compression requirement, and export specification for crude vapor pressure.
- A quick assessment of separation stages number based on FWHP is given in the table below:

FWHP, Bar	Number of Stage
1-20	1 or 2
20-70	2 or 3
Over 70	3 or 4

- The flowing tubing pressure usually decrease during the life of the field, a common practice is to install separate production manifolds for each separator.
- In this case, wells with decreased well pressure would be rerouted to a lower pressure separator, thus maximizing production. Figure 2 shows a typical flow scheme of 3 stages separation.

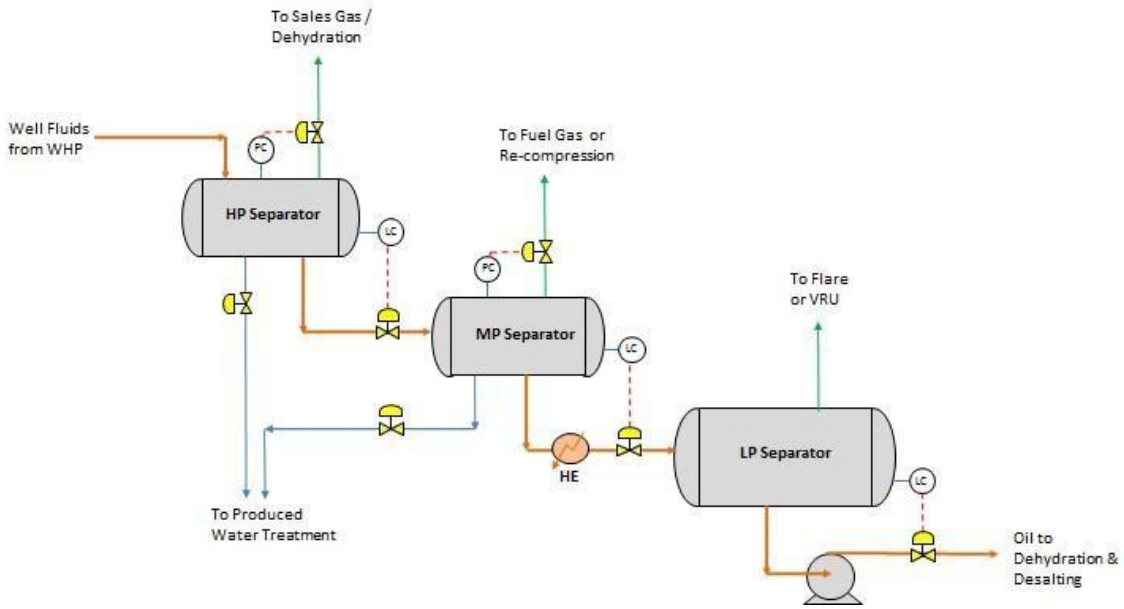

Figure 4. Typical 3 Stages Separation

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- HP separator is a 3-phase separator. The separator pressure must be low enough to allow effective choke operation and thus control of well behavior. Therefore, wells with high enough flowing wellhead pressure are routed to the HP Separator. Gas separated from the HP Separator normally flows to the gas compression and dehydration system, and then exported through pipeline.
- MP separator is similar to the HP Separator but operates in lower pressure. MP separator receives liquid (oil) from the HP Separator, and due to pressure reduction, the light components of the liquid will vaporize. Gas separated from the MP separator normally flows to an inter-stage compressor and then combines with the gas off from HP separator.
- LP separator is a 2-phase (gas/liquid) separator which operates slightly above atmospheric pressure. The operating pressure and temperature of the final gas-oil separation stage dictates the vapor pressure of the export crude. Generally stable crude (10-12 psia RVP) requires a very low pressure and high temperature.
- The **off gas** from each separation stage can be compressed and treated for use as fuel gas, exported, or flared if quantities are minimal and applicable regulations permit flaring.
- Bulk water in the well fluid is generally removed from the first stage separator, in order to minimize heating/cooling of excess liquid at further processing.
- The removed water is routed to the water treatment plant.

Separators of all types are sized according to the following parameters, to suit product specifications:

- Fluid flow rates.
- Operating Pressure and Temperature.
- Oil in Water Specification (500-1000 ppm).
- Water in Oil Specification (1-3% vol).
- Liquid losses to vapor stream (subject to demister type).
- Liquid droplet size in gas outlet (150 microns and larger droplets can be removed when internals are not used).