Surface Facilities for Oil and Gas Handling

Prof. Abdus Samad

Department of Ocean Engineering

IIT Madras

Introduction To Separators-01

Good morning, everyone. I will be starting the second week lecture. This lecture will cover different types of separators, why we separate, and the various separation mechanisms. We'll discuss gravity settling techniques, emulsion treating techniques, and heater methods. These techniques aid in separating the components of oil, water, sand, and gas from the wellbore. When you're receiving oil and water from the wellbore, envision the wellhead here. You're receiving oil, water, sand, and gas. However, your customer will not accept this fluid mixture.

As a production engineer, it is imperative to separate the oil, water, sand, and gas, as water and sand are unsellable and must be disposed of locally. Your primary product is oil and gas. When dealing with oil, a mixture of water and sand is common, so it is essential to remove these impurities. Other impurities such as H_2S and corrosive gases also need to be eliminated. Gas follows a similar process, with the removal of water or moisture particles and other impurities before it is sent to the customer. Once all impurities are removed, the oil and gas are sent to the customer. However, it is important to manage the disposal of water and sand on the surface carefully and responsibly.

When oil and gas are brought to the surface, you must remove the hydrocarbon content before disposal. We will discuss various disposal methods for water and sand handling in more detail later.

The fluid from the wellhead is directed through a choke valve, which alters the pressure. When the fluid passes through the choke, the pressure changes. As a result, the pressure at the wellhead and over the fluid on the surface will differ. A decrease in pressure can lead to a drop in temperature due to the $PV=nRT$ formula. Thus, as pressure decreases, temperature might decrease, while volume might increase. Once the fluid has passed through the choke, it is directed to a separator.

After the fluid passes through the choke, it goes to a separator, which causes a drop in pressure. For instance, if the initial pressure is 1000 psi, after the first stage of separation, it might drop to 500 psi. When you receive a mixture of oil, water, and gas, the high pressure might lead to some gas being dissolved in the liquid or oil. However, when the pressure is reduced, more gas will come out from the fluid, causing it to separate. Sometimes, there may be emulsifying agents present. An emulsion, which is like two immiscible fluids, such as oil and water, will form bubbles when properly agitated. Without an emulsifying agent, these bubbles will separate, but with a chemical agent, the oil and water won't separate.

Once again, you need to properly treat this mixture. However, the process becomes more complex when you introduce temperature and pressure variations. As the volatile gas components become more apparent, your free gas will start to emerge, and your sand will settle, allowing the water to separate. However, there are instances where the water doesn't separate due to an emulsifying agent. This agent causes the oil and water particles to form mixtures that are difficult to separate. This becomes problematic when the oil, particularly, creates foam, which doesn't separate.

Once again, determining the size of the separator becomes crucial. It could be very small, very large, or designed to be horizontal or vertical. There are various factors to consider, including the mixture's composition and the differences in pressure from different wellbores, such as well 1, well 2, and well 3. We will delve deeper into these design considerations and dimensions throughout the course.

Each wellbore has its own unique pressure. For example, wellbore 1 may have a pressure of 500 psi, wellbore 2 could have 5000 psi, and wellbore 3 might be at 5500 psi. These varying pressures mean that the fluids coming from each wellbore must be mixed and then directed to the separator. Failure to control this flow correctly can result in issues. For instance, if fluid from a high-pressure wellbore is allowed to enter a low-pressure wellbore, it could cause complications.

The complexity here is clear. To prevent high-pressure fluid from entering the low-pressure zone, you must make specific arrangements. The fluid must be directed to the separator for separation. Imagine you have a mixture of oil and water. If you don't handle this mixture correctly, the oil and water particles will form a stable emulsion that won't separate naturally. You must break this emulsion by using certain mechanisms, such as chemicals or electric fields, which disrupt the emulsion's barrier, causing the particles to coalesce and separate. There are different separation methods, one of which involves allowing the fluid to sit for a specific period.

The correct sequence of the process is as follows:

So, you have to remove hydrocarbons, then you dispose of them using different disposal methods. We will discuss these methods later in detail when we talk about water and sand handling.

Now, whenever you are getting oil and gas on the surface, the wellhead will be here. So, from the wellhead, you are passing the fluid through a choke, and there will be one valve, which is called a choke. So, when the fluid is passing through the choke, the pressure changes.

When the pressure changes, the pressure at the wellhead and the pressure of the overall fluid that you are getting on the surface will be different. After the choke, the pressure will be something different. So, you have got reduced pressure. If you reduce pressure, the temperature will also go down because of the PV = NRT formula. So, if you are reducing pressure, the temperature can also decrease, and the volume can increase. Now, you have a separator. Let's say this is the separator. So, there will also be a pressure drop in the separator. So, the pressure will be going down. Let's say the initial pressure is 1000 PSI. After the first stage of separation, the pressure might be reduced to 500 PSI.

When you are putting any fluid from the wellbore, you are getting a mixture of oil, water, and gas. Because of the high pressure, some gas will be dissolved in the liquid or oil. So, when you reduce the pressure, more gas will come out from the fluid that you are getting from the wellbore. Another issue is that sometimes there will be an emulsifying agent. Emulsion means if you have two immiscible fluids like oil and water, and you shake them properly, oil and water bubbles will be created. If you don't have any emulsifying agent, these bubbles will not separate. But if you have certain chemicals that will assist in creating an emulsion, then oil and water will not separate. So, you will need to treat this properly, and complexity comes in when you start changing temperature and pressure. Your more volatile components will come out, your free gas will come out, and your sand will get settled, but sometimes the water will not get separated because you have an emulsifying agent, and oil and water particles are forming a mixture that will not get separated easily. This can be a problem, and sometimes oil will create foam, which will not get separated.

So, how big the separator should be, whether it will be very small or very big, whether it will be horizontal or vertical, what sort of design should be there, and what are the different dimensions that should be there? These are the questions we will discuss in the whole course. There are issues like if you have an oil, water, and gas mixture, and you have different pressures from different wellbores, again it will be coming from different wellbores also, maybe well 1 will have a pressure of 500 PSI, well 2 will have a pressure of 5000 PSI, and well 3 will have a pressure of 5500 PSI.

Different pressures will be coming from different wellbores, and you have to mix up and put it in a separator. Now, if you do not control this flow properly, what will happen is that low-pressure well is there, and high-pressure well is there, so high-pressure fluid will try to enter into the low-pressure wellbore. So, the complexity is there. You have to make certain arrangements so that high-pressure fluid should not enter into the low-pressure zone, and the fluid will be going to the separator, and it will get separated.

Now, if you have an oil and gas mixture, as I mentioned, and you do not treat it properly, then the oil particle will not separate from the oil, and water particle will not get separated from oil. So, what will happen is that this will create a stable emulsion, and you have to break the emulsion. Then you have to create certain mechanisms. Some chemicals need to be put in, or an electric field has to be put in so that the emulsion's barrier will be broken, and it will create bigger particles, and it will get separated. So, there are different types of separation mechanisms. One way of separation is that you take a certain amount of fluid, and you allow a certain time, so automatically, a water-oil-water-oil and gas layer will be created. But if you have certain chemicals that are not allowing that separation, then there is a problem. So, what will you do? You have to study the whole mechanism, physics, chemistry, mathematics, so that you understand how you will separate things properly, and how you will control pressure, temperature, flow, and the level of flow rate. If you do not control the pressure, then you can create an accident. If there is any blockage, then if you do not know how much pressure is there or how much flow rate is there or how much temperature is there, then your system may fail.
When separating, controlling the process is crucial. This control involves regulating pressure, temperature, flow rate, and level. Knowing the pressure, whether it's high or low, is essential because it informs what action to take. For instance, if there's a blockage or a leak in the system, the pressure can drop suddenly. This can happen due to sand deposition or valve failure. Automatic safety valves can sometimes fail as well.

In such situations, the pressure can increase within a specific separator. Changes in pressure might cause the separator system or the entire piping system to fail, or it could pose a risk. Similarly, you must also consider the temperature because pressure and temperature are interconnected. If the pressure decreases by, say, 100 psi, the temperature may decrease as well due to the Charles's Law relationship between them ($P1/T1 = P2/T2$).

Flow rate is usually not directly controlled; rather, controlling the pressure typically influences the flow rate to some extent. Additionally, there's the aspect of level control, which I will discuss later on. It pertains to maintaining a particular level within a pressure vessel in a separator system.

In a pressure vessel, where oil, water, and gas are being separated, three layers are typically created: a top layer of gas (with very low density), a middle layer of oil, and a lower layer of water. Additionally, there may be a layer of sand deposited at the very bottom. So, let's assume these three layers: gas, oil, and water.

Now, let's consider the fluid's entry and exit points. The fluid comes in from here, and it goes out from here. But how do you remove the fluids from the separator? Since gas has a lower density, it floats on top, which is why there's a gas line here. There's also an oil line that brings out crude oil with less gas and less water. Lastly, there's a water line.

If you fail to maintain the levels of oil and water inside the separator, it can lead to issues. For instance, if the water level gradually increases and starts entering the oil outlet line, you'll end up with water in the oil outlet instead of oil. On the other hand, if the water level drops significantly, you may have an insufficient amount of water to separate the oil and gas properly. This can result in a 'foamy' oil, which isn't ideal.

If the water level is too low, oil might start coming out from the water outlet line. Therefore, it's crucial to maintain the proper levels of oil and water within the separator. The area where these layers meet, known as the interface, needs to be managed carefully. If not, the system can fail.

To achieve this, you'll need a level controller, which comes in various types. These include automatic controllers, such as hydraulic or pneumatic systems, and electronic level control systems, which are becoming more common, especially with the adoption of SCADA systems. SCADA stands for Supervisory Control and Data Acquisition, which is a system that connects all the valves, flow meters, temperature gauges, and other equipment to a central computer, typically located in an office or control room. This allows you to monitor and control the entire production process remotely, observing valve statuses, pressure levels, and identifying any blockages or malfunctions, without having to physically inspect each component.

The SCADA system acts as the central hub for controlling and monitoring operations. A master computer oversees the entire process from the control room, receiving data from the various sensors and equipment located across the production site. Automatic controllers are also integrated into the system. These controllers continually monitor various parameters such as pressure and temperature. If any anomalies are detected, such as a blockage, the system can take corrective actions autonomously or prompt operators in the control room to intervene.

In the case of an emergency or a critical issue, the SCADA system can swiftly alert operators or initiate pre-programmed responses to mitigate the situation. It serves as a comprehensive solution for the continuous monitoring and control of production operations, ensuring safety, efficiency, and optimal performance.

So, if the level changes from 2 to 1 centimeter or 5 to 10 centimeters, it indicates a fault in some cases. Detecting and addressing such issues promptly is crucial to avoid potential disasters in the future. Therefore, maintaining proper level control is essential. Pressure monitoring is also crucial. If you monitor and control these parameters effectively, all the data can be channeled into the master computer system, which is the data acquisition system.

Now, let's talk about the principle of separation. Why is separation important? Because your customers will not purchase oil if it contains an unacceptable amount of solid content, gas content, or water content. They have specific requirements; for example, they might not want more than a certain percentage of moisture or solid content. The separation process is also essential for safety reasons. After separation, the fluids are stored in storage tanks.

After the separation process, the fluids are stored in storage tanks. This is because the storage tanks typically operate under atmospheric pressure. This means they are designed to work under standard conditions, which are usually assumed to be 14.7 psi (PSIA) and 60 degrees Fahrenheit. These conditions might vary depending on the location; for instance, in Chennai or Alaska, the temperature might be different. However, under standard conditions, volatile components are not present in the fluid.

Before sending the fluids to customers, it's essential to check the moisture content. The moisture content must be within specified limits or less than that to meet the customer's requirements. Additionally, the presence of other components, such as H_2S, should also be considered and measured.

So, typically separation principles involve centrifugal action or gravity separation. In centrifugal action, fluid is injected into the separator at high velocity, causing heavier particles to fall and form a layer. Meanwhile, any gaseous components will naturally rise. This separation process ensures that heavier particles are separated from the fluid, making it possible to obtain the desired product. Additionally, other techniques like gravity separation and chemical treatments may be employed to further refine the separation process.

Correct, gravity separation and centrifugal action are essential for separating the liquid and gas phases initially. It is crucial to have a large settling section to allow sufficient time for the two phases to separate effectively. This time is referred to as the retention time, and it is the duration that the fluid spends inside the separator, during which the liquid and gas phases are allowed to settle and separate. Maintaining the proper retention time is critical for the effective separation of the fluid components within the separator.

Exactly, the retention time is a critical factor in the separation process. If the vessel is small and the retention time is too short, the particles will not have enough time to settle, leading to incomplete separation. Conversely, if you allow for a longer separation time, such as one to four months, you'll achieve a more thorough separation. In this scenario, the oil particles will gradually rise to the top, while the water particles sink to the bottom. This extended separation time results in a very efficient and effective separation process. However, in practical applications, the process typically needs to be much faster, and the design of the separator must balance the competing needs of efficiency, speed, and other factors.

Absolutely, you've succinctly captured the essence of the design challenge faced by engineers in the separation process. We aim to achieve the desired separation efficiently and reliably within a constrained timeframe, which typically involves much shorter intervals than the months-long ideal you've described. This objective often requires a delicate balance between the flow velocity, flow rate, and the physical dimensions of the separator—its diameter, length, etc. Optimization then becomes crucial, as we determine the optimal flow rate and pressure, manage the centrifugal action and satellite section dimensions, and strive to maintain a compact yet effective system.

The crux of this endeavor lies in designing a separator that provides the necessary retention time for efficient separation while operating within the practical constraints of the process. Achieving this balance involves sophisticated calculations and a deep understanding of fluid dynamics and separation principles.

Indeed, a separator is essentially a pressure vessel and thus must adhere to strict design standards, particularly regarding its thickness and material selection. The thickness of the pressure vessel is a critical factor, ensuring the structural integrity and safety of the separator under varying operating conditions. Factors such as internal pressure, corrosion, and erosion due to sand particles and H2S must be considered.

For instance, the material selection for a separator vessel often depends on factors such as:

1. Corrosion Resistance: The vessel material should be resistant to corrosion, which could be caused by H2S, moisture, or other contaminants in the fluids being separated. Stainless steel or corrosion-resistant alloys are commonly used in this regard.

2. Erosion Resistance: Sand particles in the fluids can lead to erosion of the separator walls over time. The vessel's material should have a high resistance to abrasion to minimize wear and extend the equipment's lifespan.

3. Mechanical Strength: The material should have sufficient mechanical strength to withstand the pressure and temperature conditions inside the separator. Carbon steels, alloy steels, or specialized materials such as Duplex Stainless Steel are often used for their high tensile strength.

The design and material selection process must also account for other factors such as temperature and operational considerations like cleaning and maintenance procedures. Achieving a balance between these requirements is crucial to designing an effective, durable, and safe pressure vessel separator.

Correct, you mentioned many crucial aspects to consider during design and operation. Here is a more detailed overview:

1. Cleaning: Regular maintenance and cleaning procedures are essential to ensure efficient operation and longevity of the separator. Depending on the design, separators may include various cleaning mechanisms such as sand jets, mechanical scrapers, or automatic backwash systems. These help remove accumulated solids or other contaminants from the separator.

2. Leakage and Rupturing Prevention: Leak prevention and pressure vessel integrity are critical for safety and environmental protection. This involves choosing appropriate seals, gaskets, and materials that can withstand the operating conditions and the fluid being handled. Routine inspections and regular maintenance help identify and address potential leak points before they become problematic.

3. Temperature and Pressure Control:Monitoring and controlling temperature and pressure within acceptable ranges is crucial for efficient operation and product quality. Automatic control systems or relief valves can help maintain desired pressure levels, and temperature sensors can trigger cooling or heating mechanisms to keep fluids within optimal ranges.

4. Cost Limit and Optimization: Design and operation must also consider cost-effectiveness. This involves optimizing various aspects such as equipment size, material selection, energy consumption, and maintenance costs to achieve the desired separation efficiency while minimizing operational expenses.

5. Role of Production and Application Engineers:Engineers involved in production and application must be well-versed in the technical specifications, performance requirements, and operational constraints of the equipment. They should work closely with design and sales teams to ensure that the final equipment meets the specific needs of the project or application.

6. Supplier Communication: It's important for production and application engineers to have open communication with equipment suppliers like Vicarages or Schlumberger. While the sales team may provide initial information, technical teams should engage to ensure that the selected equipment meets the project requirements in terms of design, performance, and safety.

In summary, the successful design and operation of a separator involve a multidisciplinary approach that considers various parameters such as cleaning, leakage prevention, temperature and pressure control, cost optimization, and effective communication between engineers and equipment suppliers.
a crucial aspect of purchasing or recommending equipment is ensuring that it aligns with the project's specific requirements. Just because a sales team recommends a product does not guarantee that it's the right fit for your needs. It's the responsibility of the engineer to thoroughly evaluate the product's technical specifications, performance capabilities, and compatibility with the operating conditions. The goal is to achieve optimal production efficiency, which in turn leads to higher profits and lower maintenance costs over the system's lifespan.

It's also essential to consider the entire system's integration, not just individual components like separators or heaters. Each piece of equipment in the production line must work harmoniously with others to ensure the entire process is efficient and reliable.

Effective communication and collaboration between different teams, including design, sales, and technical, is vital to selecting the right equipment and ensuring its seamless integration into the production system.

A critical aspect of the oil and gas production system is a complex network of interconnected components, and each element plays a vital role in the overall efficiency and effectiveness of the system. These elements include vertical and horizontal separators, cyclone hydro cyclones, scrubbers, contact columns, and more. All these elements must work together in a synchronized manner to ensure optimal performance.

When there's a change in reservoir pressure, it can have a significant impact on the operation of the entire separator system. In some cases, this may require additional equipment, such as an extra compressor, to maintain the required pressure levels throughout the system. However, a small pressure reduction may not significantly impact the overall operation of the separator system, and minor adjustments can be made to ensure continued efficiency and productivity.

As a production engineer, you're responsible for the entire production process from the reservoir to the final product. This includes understanding the reservoir itself, how to extract the oil through artificial lifting techniques, the flow performance through the tubing and piping systems, the operation of valves, and the function of the separator system, among other things.

By having a deep understanding of each component and process, you can optimize the overall production process, minimize losses, and ensure safety. In the course, I'll explain each of these components and processes in detail so that you have a comprehensive understanding of the entire production system.

A separator is a type of pressure vessel, specifically designed to handle and separate different phases of fluids, typically oil, gas, and water, in the oil and gas industry. A pressure vessel like a separator is built to withstand the internal pressure created by the fluids, which can be quite high.

When designing a separator, engineers consider the working pressure, temperature, and the type of fluids involved. The vessel is then built with materials that can handle these conditions. This ensures the safety and efficiency of the separator system.

The separator may include other features like baffles or coalescers to help in the separation process, as well as valves and safety systems to manage pressure fluctuations and prevent accidents. The whole system is carefully designed to handle the complex interplay of different fluid phases and optimize production efficiency.

A mist extractor, also known as a demister, is a device used in a separator to remove small liquid droplets or mist from gas. In a separator, gas flows horizontally and rises while liquid droplets fall and sink. If these liquid droplets are not removed, they can cause issues downstream, such as blockages in pipelines or contamination in processed gas.

The mist extractor typically consists of a mesh or wire pad, often in a cylindrical shape, placed inside the separator. As gas flows through this mesh, the liquid droplets collide with the mesh and coalesce into larger droplets. These larger droplets are heavy enough to fall back into the liquid phase and are thus removed from the gas.

The effectiveness of a mist extractor depends on factors such as the velocity and volume of gas flow, the mesh density, and the physical characteristics of the liquid droplets. By capturing and removing these liquid droplets, the mist extractor helps improve the quality of the gas stream, ensuring downstream processes are not compromised.

Absolutely, that's a crucial aspect of maintaining optimal performance in your separator system. The control and monitoring mechanisms are essential for ensuring that the system is operating within the desired parameters and that any deviations from those parameters are identified and corrected promptly.

Solenoid valves play a vital role in this as they allow for remote and automatic control of flow rates and pressure within the system. They provide a highly efficient way to make adjustments without requiring manual intervention, thus enhancing the overall efficiency of the system.

The SCADA system is particularly valuable in this regard as it provides real-time monitoring and control capabilities from a centralized location. This enables operators to make informed decisions quickly and ensure that the separator system operates smoothly and safely.

Emphasizing the importance of environmental responsibility in oil and gas production and minimizing the production of water and sand by utilizing effective separator systems and sand control mechanisms can significantly contribute to reducing environmental impact and improving operational efficiency. You are also pointing out that, while it may not be possible to eliminate water and sand production entirely, the goal is to optimize the process to minimize these by-products.

You also mention the critical role of separator systems in handling oil, gas, water, and sand separately to maximize profitability. Your emphasis on environmental considerations and sustainable practices reflects a conscientious approach to the oil and gas production process, ensuring that it aligns with regulatory standards and environmental protection goals.

Indeed, in modern separator systems, automation and remote monitoring have become increasingly common, reducing the need for direct manpower onsite. The primary function of a separator is to efficiently separate the various phases present in the production stream, such as oil, gas, water, and sand. By doing so, the valuable hydrocarbons can be handled separately for further processing, while the unwanted components like water and sand are removed and disposed of appropriately.

Minimizing the production of unwanted by-products, such as oil and gas, is crucial to streamline operations and minimize environmental impact. This entails implementing effective sand control mechanisms and optimizing production rates to reduce the amount of water and sand produced. While achieving zero water and sand production may not be feasible, efforts should be made to minimize their presence and handle them responsibly on the surface to comply with environmental regulations.

Overall, efficient separator operation and proper management of by-products are essential for maintaining operational efficiency, minimizing environmental impact, and ensuring regulatory compliance in oil and gas production.