Artificial Lift

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Lecture-01 Introduction to Oil and Gas

Today, we are starting a new course called Artificial Lift. Artificial lift has been utilized in the oil industry for several years, and various types of artificial lift techniques are employed to bring fluids from the wellbore to the surface. These techniques include sucker rod pumps, electric submersible pumps, jet pumps, and gas lift systems. However, it's important to note that not all these methods can be used in every wellbore.

This lecture will cover the different techniques used for various wellbore conditions, such as low pressure, high pressure, low sand, high sand, low gas, high gas, and deviated wellbores. Considering these diverse wellbore properties, it becomes clear that a single artificial lift method cannot be universally applied. To make an informed choice, you need to understand the pumping equipment's wellbore properties and mechanical capabilities. You must understand the underlying physics and mathematics to bridge these two aspects effectively. The course will primarily focus on providing an introduction to the oil and gas industry since this is the first course in the series. Therefore, I am laying the groundwork by introducing fundamental concepts related to oil and gas.

Next, I will cover various topics, including multiphase flow and oil and gas properties. Additionally, I will discuss reservoir properties because understanding reservoir properties is essential for properly utilizing any artificial lift system. You need to be familiar with both fluid properties and reservoir characteristics. I will then introduce artificial lift methods and when to use each type of artificial lift. I'll explain the selection criteria and discuss each artificial lift method individually. For example, I will start with the sucker rod pump, a beam pump. When searching for information about the sucker rod pump, use terms like 'beam pump.' In Google, you can search for terms such as 'beam pump,' 'sucker rod pump,' or phrases like 'nodding donkey' or 'horse head' to find more information about this type of pump. The next system we'll delve into is the gas lift system. Gas lift is employed in wellbores with lower reservoir pressure. Injecting gas creates multiphase flow, which helps lift wellbore fluids to the surface. To implement this technique, you'll need a gas surface compression system to increase the pressure of the injected gas.

You cannot use air because it contains oxygen, and mixing oxygen with wellbore fluid would create a combustible mixture. Instead, you can inject Nitrogen, an oxygen-free gas, or use the produced gas from the wellbore. Injecting the same gas can enhance productivity. The next option is the progressive cavity pump, or PCP, designed for pumping highviscosity fluids. Some say the progressive cavity pump is a 'progressive thinking' pump because it works when other pumps fail, making it suitable for extracting fluids from wellbores. It can handle fluids with viscosities ranging from 1 Cp to 1000 Cp, such as grease, toothpaste, or fluids used in the food processing industry. While its energy performance or efficiency is lower, it excels at handling highly viscous fluids.

Another option is the jet or hydraulic jet pump, a technology familiar to mechanical and chemical engineers. In a hydraulic jet pump, a narrow channel is created where flow velocity increases, leading to a decrease in pressure. It can suction other fluids at low pressure, making it suitable for wellbore pumping. There are two types of hydraulic pumps: the hydraulic jet pump and the hydraulic engine pump, which I'll discuss in the lectures. The lectures will cover theoretical basics along with mathematical calculations. Towards the end, I will revisit and explain which options are better suited for specific applications. I will also present models for designing and provide practical insights.

Moving on, it's essential to understand the term's origin when discussing petroleum. Petroleum is derived from 'petrus' and 'oleum,' where 'petrus' means rock and 'oleum' means oil. Petroleum is essentially 'rock oil.' Deposits of materials like plankton or phytoplankton accumulate on riverbeds or seabeds. Over time, under the influence of temperature and pressure, these deposits undergo chemical changes and transform into petroleum, which includes products like diesel and petrol used in vehicles. This course is closely related to the petroleum industry. To truly grasp petroleum production, one must delve into various fields, including physics, mathematics, geology, geophysics, reservoir engineering, mechanical engineering, and chemical engineering. We can only extract the petrol or diesel that powers our bikes and cars.

When you consider petrol, you visit a petrol station to purchase it. But where does this petrol come from? Petrol is sourced from a refinery. However, the refinery doesn't directly obtain oil and gas from the wellbore; it must be purified before reaching the refineries. In actual practice, there is an exploration phase. Initially, you assume the presence of oil and gas in an area and estimate the potential reserves. Afterward, you drill a hole. But you can't immediately extract oil and gas because they are combustible and potentially hazardous to the environment. If you don't properly treat or handle the produced oil or gas, it can lead to environmental disasters, fires, or other problems.

In such cases, you need to complete the wellbore, which involves a process I'll explain later. Proper completion includes casing the well with pipes, cementing it securely, and then creating a hole. This entire procedure is referred to as 'completion.' Following completion, you move on to the separation or production phase. During this phase, you extract a mixture of oil, gas, sand, and water from the wellbore and bring it to the surface. Once on the surface, it goes through a separator system.

So, what does the separator system do? It separates oil, water, gas, and sand. Here, it would help if you determined which products are required. The required products are gas and oil, while water and sand are unwanted. However, due to environmental hazards, you can't dispose of water and sand randomly. There are specific procedures to treat or remove oil particles from the water or sand, after which you can use them for a specific purpose, inject them into the wellbore, or dispose of them elsewhere. When dealing with gas, it can contain substances like H_2S or other chemicals, possibly with traces of water. In such cases, unwanted chemicals must be separated from the gas before being supplied to customers. In India, for instance, gas is supplied to homes by Indian Oil and Oil India.

Now, the oil you receive is crude oil, meaning it's thick and yellowish. You can't use it directly in your bike, car, truck, or train. It would be best to modify its properties to make it thinner, like petrol, slightly thicker as diesel, thicker as lubricating oil, or thicker as wax. This separation and modification process is necessary before use. Once you have the oil, you must properly remove all water particles, sand, sediment, and impurities. After that, you transport it to a refinery, not directly to the customer. This refining process further transforms the oil for various purposes. In the ecosystem of oil production, artificial lift plays a crucial role. Initially, it is involved in drilling and completion, as a well that isn't appropriately completed can't achieve an economically viable production rate. Cementing is a vital step when you drill and complete a hole. The oil industry refers to this casing as 'cementing.'

Now, the wellbore is ready for production, but there are still some issues. You've put casing and cementing in place. Now, this is the reservoir, and you assume oil, gas, water, sand, or other substances are in it. However, due to the casing, wellbore fluid can't enter directly. So, what do you do? You create a series of perforations, many small holes, allowing the oil and gas to flow through them. The fluid will enter through these perforations, move up the wellbore, and at the surface, you have a separator mechanism. You separate the components using this separator and send them to refineries and customers. Now, what happens if the reservoir pressure is very low? In that case, the wellbore fluid, comprising oil, gas, and more, won't naturally flow to the surface or separator. That's when you need an artificial mechanism. If there's sufficient reservoir pressure, the fluid will naturally rise to the surface, called natural flow.

However, if the reservoir pressure isn't sufficient to lift the fluid from the wellbore to the surface, you need an artificial mechanism. This can be artificial lift or other techniques like steam injection or water injection, but we'll focus on artificial lift. Artificial lift is used when natural flow isn't possible due to low pressure. Sometimes, it's employed to increase productivity. For instance, if you're producing 500 barrels per day and want to increase it to 700 barrels, you implement an artificial lift mechanism to achieve the desired productivity. Looking at the history of oil and gas, people have been using them for energy purposes for over 5,000 years. The first oil wellbore was drilled in the United States in

1869. In India, the first wellbore was created in Assam. An exciting story goes along with it: At that time, the Assam Railway Company, led by a Canadian engineer, was laying railway tracks. They used elephants to transport their wooden tracks and found black, oily fluid—most likely oil—during the process. It was so oily that it even stuck to the elephants' legs.

So, the laborers said, 'Sir, there is oil,' but the British Canadian engineer replied, 'Boy, dig! Boy, dig!' So, that's how the term 'dig boy' came into being. I don't know the exact origins, but there's a lot of information and stories about it on the internet, so you can also search for more details. Then, the British government started the first oil wellbore; I believe they created Well Number One in the Digboy area. To this day, the Indian government has established a museum in that area to showcase the first Indian wellbore.

India also discovered oil in Mumbai High, which provides a significant portion of the country's energy needs—about 14 percent. Other areas like Gujarat, Rajasthan, Tamil Nadu, and many more have also yielded oil and gas reserves. Despite numerous wellbores and ongoing activities, India doesn't produce enough oil domestically. It imports more than 80 percent of its oil and gas requirements from other countries, a significant expenditure. Even though there's a growing reliance on renewable energy, predictions suggest that the need for oil and gas will persist for the next 50, 60, or even 100 years. While the dependence on oil and gas may decrease in some areas due to adopting renewable energy systems, there are still essential applications. For example, plastics, medicines, and various items rely on petroleum-based products, including petrol and diesel for vehicles.

The term 'peak oil' has been coined, suggesting that we may have reached the peak of oil production, and it's gradually declining. However, ongoing exploration efforts still uncover new wellbores, leading to increased production. There's still a chance of discovering more reservoirs, perhaps in deep waters or even the Himalayas. However, it's unlikely that India will be able to produce all the oil and gas it needs domestically. Several countries, such as Russia and Saudi Arabia, are significant producers of oil and gas, contributing the highest volumes to the global market.

But in terms of consumption, we find the highest consumption in the US, with China and India following closely, I think India ranks third or fourth in terms of consumption. There's also significant consumption in India, but we're not producing enough, leading to a substantial gap. The Indian government is working to address these issues. In terms of oil and gas composition, the major component is carbon, making up around 83 to 85 percent. Hydrogen comprises 10 to 14 percent, while Nitrogen is around 0.1 percent. Oxygen ranges from 0.05 to 1.5 percent. Sulfur content can vary from 0.05 to 6 percent. We don't have any metal content, such as sodium or potassium. Carbon and hydrogen are the primary constituents, forming hydrocarbons, which provide the main energy source.

However, sulfur is a significant concern in the oil and gas industry. If the sulfur content is high, it can lead to corrosion. When sulfur combines with oxygen, it forms SO_2, which can further react with water to produce H_2SO_3 or H_2SO_4. These compounds can corrode metal pipes. For instance, when H_2SO_4 reacts with iron, it creates $FeSO_4$ and H_2. Ferrous sulfate, formed on the surface of iron, is a softer material that leads to increased corrosion and erosion rates. Therefore, managing sulfur content is crucial for the oil and gas industry.

$S+2O \rightarrow SO_2$

$SO_2+ H_2O \rightarrow H_2SO_3$ or H_2SO_4

$H_2SO_4 + Fe \rightarrow FeSO_4+ H_2$

Many times, the oil and gas industry handles surface treatment systems. They then send the product to the customer, who may have specific requirements. For instance, they might specify the oil or gas's BSW (basic sediment and water) content. Based on these specifications, they certify the quality. If your petroleum product has a higher amount of BSW or solid and water content when supplying to refineries, they may refuse to purchase it, considering it of lower quality due to inadequate separation. Therefore, maintaining quality during the oil and gas separation process is essential.

Regarding reservoirs, I've mentioned the term "reservoir" several times. A reservoir is formed when numerous organisms or animals accumulate on the seafloor, and layers of sand gradually build up. Over time, with the right temperature and pressure conditions, this material transforms into Bitumen. This Bitumen then undergoes diagenesis, a set of reactions resulting in the formation of hydrocarbons. Water and other compounds are released during this transformation, leaving behind primarily hydrogen and carbon-based compounds. This process leads to the creation of oil and gas within the reservoir. To form a reservoir, you need a source rock, where oil and gas are generated, and a permeable rock. Permeable rock allows for connectivity between small pockets within the source rock, enabling oil and gas extraction. However, having permeable rock alone won't yield oil and gas because if there's no covering or sealing layer over the reservoir, applying high pressure could cause the gas and liquid to escape. To prevent this, you need cap rock or a solid, impermeable layer that covers the oil and gas reservoir, keeping them contained.

So, here's what happens: I will draw an upper crust. There may be gas, followed by a liquid layer, oil, and more gas. There may also be another gas cap, followed by solid or cap rock. The cap rock is permeable, and this layer acts as another cap; I'll use a different color to represent this second cap. When the cap rock is present, gas cannot escape, so it gets trapped here. When you drill a hole in this reservoir, you can extract gas or oil. Whenever oil and gas are in a reservoir, you typically prioritize extracting oil first. If you remove gas first, the pressure will drop, making it more challenging to extract the oil. Gas will naturally expand, contributing to production. Now, let's talk about petroleum formation. It occurs in three steps: diagenesis, catagenesis, and metagenesis. During diagenesis, temperatures are around 50 degrees Celsius. Catagenesis occurs at temperatures between 60 to 200 degrees Celsius, and metagenesis occurs at temperatures above 200 degrees Celsius.

During diagenesis, Bitumen is formed, while catagenesis creates petroleum, such as petrol or diesel. Metagenesis, occurring at even higher temperatures, can lead to the formation of substances like graphite or even diamond. Petroleum forms due to the deposition of phytoplankton or animals in the seabed, which subsequently transform due to temperature and pressure. Catagenesis and diagenesis can be visualized as follows. First, you start with all these living organic materials: lignite, lignin, carbohydrates, proteins, and lipids, which all contribute to forming fulvic acid. From fulvic acid, you move on to produce kerogen. Thermal degradation occurs in kerogen, leading to cracking. This cracking results in carbon residue or even graphite formation as you go deeper. Depth, temperature, and time all increase due to continuous sedimentation. Kerosene production leads to Bitumen, a heavy hydrocarbon, and eventually, crude oil.

On the other hand, natural gas contains various constituents when extracted from a wellbore. It may include Sulfur, Oxygen, and traces of Nitrogen but predominantly consists of methane, making up 70 to 90 percent of its composition. When natural gas is collected, a contactor column separates and obtains pure or dry sweet natural gas, which can be used for cooking, gas turbine operation, or various other purposes. Some other components present are C_2H_4, C_3H_8, and C_2H_6. Compounds like methane (CH_4), ethane (C_2H_6), and propane (C_3H_8) are also found, but their percentages decrease gradually. Methane is a lightweight molecule that is more volatile, leading to natural gas formation. As the hydrocarbon chain lengthens, it slowly transitions into a liquid state.

The chemical reaction for CH_4 combustion is as follows:

$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$ + energy.

Burning CH_4 generates a significant amount of energy. It is typically odorless and colorless, but for safety reasons in commercial applications, additives such as mercaptans are often introduced to give it an odor. For favorable petroleum accumulation, several conditions must be met. High organic content in the source rock is necessary. Source rock is where organic materials are deposited and transformed into petroleum. Rapid burial and a reducing environment are required, along with sufficient overburden pressure to facilitate the natural maturation process and chemical changes. Porous rocks are essential as they ease the movement of hydrocarbons, and there must be pressure accumulation traps. These traps should be capped by rocks with higher pressure to enable the conversion of hydrocarbons. These are the fundamental criteria for accumulating petroleum in reservoirs, specifically oil and gas. The next lecture will delve into lifting fluid from the reservoir to surface.

******Thank you very much*****