

Lecture 3: Drilling Mud and Mechanisms of Recovery of Petroleum

Hello and welcome to the third lecture on Petroleum Technology. Here, I will discuss the drilling fluid or drilling mud and the mechanisms of the recovery of petroleum. So, now come to the discussion on drilling mud. We have already mentioned the drilling mud in our last lecture. Drilling mud or drilling fluid is an important component in the rotary drilling process. Here what is done: the drilling fluid is used during the borehole drilling and the drilling fluid is a component used while the rotary bit is rotating at the tip of the drilling string and goes inside the drilling well and cuts the soil chunks.

So, in this process, the drilling fluid is poured into the drilling string inside and after that, it reaches the tip at the drilling bit and comes out through the annular space between the drill string and the borehole. So, it is a critical component in the rotary drilling process. While the drilling fluid is inserted into the drilling string, a mud pump is required along with a circulating system. So, a circulating system is used to circulate the drilling fluid down to the drill stem or drill string and up the drill stem to the borehole annulus. Drilling mud composed of a mixture of water, bentonite clay, may be bentonite or other clays may be used, but mostly bentonite is used. Weighing material may be barite and some chemicals. Drilling mud is prepared and conditioned in mud pits. Mud pits are large steel tanks with some agitators associated with them to maintain the density of the drilling fluid in suspension. There are some important functions of drilling fluid. As I said, drilling fluid is introduced into the drilling string when the borehole is made, borehole is drilled. So, you understand that whenever the cutting action of the drilling bit is going on, a large amount of heat is produced at the tip of the drilling bit, and the drill string also gets heated. At this condition, if the temperature of the borehole increases inside, it will change the borehole pressure as well as the oil and gas pressures. So, we need to cool the drilling bit as well as the drilling string and for this purpose, drilling mud is introduced. So, cooling and lubricating the drilling bit and drilling string is one primary function. The next one is to remove drilled solids, allowing their release at the surface. Whenever the drill bit is cutting the soil parts and also the rock cuttings, they are inside the drilling mud. So, when the cutting action is going on, the drilling mud retains those cutting chips and maintains them along with the borehole annular space. Next is to form a gel to support drill cuttings and any weighing material when the fluid column is static. One situation may come when we have to stop the drilling operation. At that time, the mud pump is switched off, but the drilling fluid inside the borehole, as well as inside the drill string comes at the same level and forms a gel inside. So that it can carry the drill cutting inside and keep them in suspension; the drill cutting should not fall into the drill bit position.

So it does not allow the drill cuttings to fall. It makes the drill cutting remain within the drilling fluid. The next one is to control the subsurface pressure. Drill fluid makes a column inside the borehole and it maintains the pressure of the column. To prevent squeezing or caving of formation, plaster the sides of the borehole. Obviously, whenever it makes a static column inside the borehole, it prevents the squeezing of the borehole as well as the caving of the borehole and it plasters the wall of the borehole. So, that it prevents the water or any oil from other formations from coming inside the borehole. Now, there are several oil recovery forces that are responsible for recovering the oil from the borehole to the surface of the reservoir. And the rate at which oil, gas and water, (we cannot escape from water because water is always associated with oil and gas), so, oil, gas, and water in the reservoir core space can flow to the surface depending on several vital factors. The first one is the pressure difference between the reservoir and the well. Obviously, the more the difference in the pressure between the reservoir and the well, the more the amount of recovery. More amount of oil and gas can get expelled out of the well. The next point is the permeability of reservoir rock. So, one condition of being a reservoir rock is to be porous as well as permeable. So, reservoir rock should be permeable and its permeability should be perfect so that we can recover the oil from the pores of the reservoir rock.

The third point is reservoir thickness. The thicker the reservoir, the more the content of oil and gas in it. So, there is a possibility of recovering more amount of oil and gas from the reservoir. The fourth point is the viscosity of the oil. If the oil is less viscous, that means, the oil is light, then obviously, we can recover more oil at a lesser force or lesser exhaustion than the dense oil.

Dense oil needs more force to employ or more force when it gets consumed. There are several means that serve to drive the petroleum fluid from the formation through the well to the surface. So, we will now study what are the means by which we can recover the petroleum fuel from the well to the surface and from the well to the reservoir rock, that will come out to the surface. Now, coming to various classifications of those drives or those forces, drives are various forces. Coming to the first one is the natural drive, which is also said to be the primary recovery.

Under this, coming, dissolved gas drives, gas cap drives, and water drives are the major natural drives that we see to employ. The next one is improved oil recovery IOR, which is also said to be a secondary recovery. Secondary recovery is employed when all the natural forces are already exhausted and we do not get any more oil from the well by using the natural forces. Next, we employ this secondary oil recovery for the drilling of horizontal wells, multilateral wells and extended reach wells.

All these we have already covered, but still, I want to mention more that whenever a reservoir is not exhausted, some oil is still there at some difficult zones which we cannot

sweep part of. We can take the oil by drilling the horizontal well. Horizontal wells cover the whole part of the reservoir rock and it can go up to some difficultly reached portions. Similar to multilateral wells, many wells can be drilled throughout the area of the reservoir so that we do not leave any portion bypassed. Third is the extended reach well, which is the well that is dug when it is difficult to go straight vertical well drilling. Water and gas injection too are those where we introduce extra energy into the well by injecting water and gas.

Now, the third type of recovery is called enhanced oil recovery, EOR or tertiary recovery. Here, actually, this recovery is done when secondary recovery is also not in use. We have exhausted all the types of forces or all the types of mechanisms that we can make by the natural drive and secondary recovery. So, enhanced oil recovery is introduced at that place. Here, we introduce energies to the wells, which energies can change the physicochemical properties of the fluid as well as the rock. Those are the introduction of gas underground. There may be hydrocarbon gas, carbon dioxide, nitrogen, flue gas, etc.

Introducing some chemicals such as surfactant, polymer, gel, etcetera and thermal energy that mean, heat energy you can introduce by the use of steam or in situ combustion. Now come to the natural drive or primary recovery from which we can expel lots of oil and gas from the reservoir rock. So, petroleum is propelled out of the reservoir through the well by one of the three methods or combinations of them: dissolved gas drive, gas cap drive and water drive. When the reservoir is there under the ground it is under high pressure and at that pressure, it is called the unsaturated reservoir rock, because the pressure is more than the bubble point pressure of the fluid inside it. Now, whenever we drill a well slowly the pressure is released at the very beginning. When the pressure drops down slowly, the oil, water, and rock expand and in this procedure, some amount of oil and gas comes out. That is called expansion drive which is the first stage of force that is employed to get some small amount of oil and gas from the reservoir rock.

After this, as the pressure is released further gas bubbles are formed which come out from the oil because previously all the gases were dissolved in the oil slowly. After releasing the pressure, the gas comes out from the oil, taking some volatile components of the oil along with it and comes above the **force** and then releases it. So this is called dissolved gas drive. At this stage, the bubble point pressure of the fluid becomes the same as the reservoir pressure or maybe the reservoir pressure may be lesser than the bubble point pressure. This condition of reservoir rock is called saturated rock. Now more pressure drops down and then the gases come up from the oil and make a gas cap on the top of the reservoir rock and this gas cap along with it takes out some oil and expels the oil. This is called gas cap drive. Some of the hydrocarbons are associated with water-bearing rocks. As the pressure drops down more than that water-bearing rocks which are also called

aquifers, release energy, which means, more water comes out and it expels the oil from the pores, out of the pore, which is called water drive. So, all these three are the natural energy or natural forces that are used to take out the oil deep from the reservoir rock.

We will see now how much percentage of oil we can recover from different natural drives. The very first one is the expansion drive from where we get a small amount of oil, already said, it is because of the expansion of oil rock and connate water. It is 1 to 5 percent what is connate water. I must mention here, connate water is some amount of water which is already always associated with oil and gas. They make a water collar at the pore. So, that is what expands in the expansion drive. So, expansion of oil rock and connate water gives us 1 to 5 percent yield, solution gas drive gives us 5 to 25 percent recovery, gas cap drive gives 10 to 35 percent recovery and water drive gives the highest amount of 20 to 50 percent. Now, coming to the secondary oil recovery or improved oil recovery IOR, so, any activity that releases, increases the recovery above that of the primary recovery. Here again, I must say one point: this improved oil recovery is done without changing any physicochemical properties of the fluids and rock.

Under this, I have already covered different types of drilling extra wells or horizontal wells, directional drilling, or inclined drilling. So, these extra wells can take out the oil that we could not reach at the time of natural drive. Next comes the addition of external energy to the reservoir, obviously by injecting water and gas. Water is injected through one well, which is called the injector well and oil is produced from another well, which is called the producer well. This is a water drive by an improved oil recovery process.

Now from one well whenever we inject the water it pushes the oil through another well and the more water we inject, more will be the energy we add to the reservoir. Another drive is the gas drive. Gas drive is similar to the water drive. Gas may be miscible or immiscible to the oil and oil is expelled by the force of the gas that we have injected. Sometimes oil sometimes water are also injected with the gas and many a time it is seen that gas injection is done when there is a gas cap on the top of the reservoir rock. Next, we are coming to the tertiary recovery or enhanced oil recovery.

Whenever the natural drives and secondary drives are over, whatever amount of oil is still remaining under the earth in the pores, say, maybe the difficult pore structures or less permeable portions we can use this enhanced oil recovery. It involves extra external energy and creating fundamental changes to the physicochemical properties of the system. So, there are two major types of EOR. One is the action of oil droplets trapped in the pore. Whatever oil droplets still remain in the difficult-to-reach portions, is one target. So, the mechanisms are mass transfer by gas pushing the gas through that portion, another one is lowering of interfacial tension by surfactant.

Whenever we use surfactant obviously, the surface tension is lowered and the oil can be recovered easily. The next target is the action of oil trapped in unswept areas that are also may be difficult to reach portions that were unswept. So, the mechanism may be the increase in water viscosity by polymers or foam. If we increase the water viscosity, water can push more the oil. So, that oil can go out of the pores.

The next one is the reduction of crude oil viscosity by carbon dioxide stream. So, the lesser the viscosity, easier the production of crude oil. So, this is another mechanism and the third one is in situ combustion, putting heat into the reservoir rock. So, that oil becomes thinner and it can come out easily. This is the life cycle of a reservoir's typical production profile.

You see this x-axis is time and the y-axis is production rate. At the very beginning, it is the discovery of the reservoir rock that starts up. The production rate increases with time and after it reaches a particularly high rate of some 1 to 10 years' time, it remains highly produced well. And after that period slowly the production rate drops down and then again investing some amount of money in repairing and workovers etcetera and introducing secondary and tertiary recovery IOR and EOR some amount of production rate we can get more and after that, the well is abandoned when almost there is no production along with the time. This is the economic profile, the x-axis is time and the y-axis is dollar.

So, at the beginning obviously, this is the investment zone where we are investing behind drilling and development and pipelines, etcetera and it consumes money. And after that, slowly, we are reaching above and the payback period starts. So, that part when it goes at a hike is the profit-making period, and we get higher oil prices. Obviously, we have to get some little profit because of the reason we have to go for maintenance expenditure and after that when the well is abandoned the oil price obviously, drops down and we do not make any more profit.

These are the references. Thank you for your attention.