Petroleum Reservoir Engineering

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Lecture – 4

Well Drilling Methods

Hello everyone and welcome again. In this lecture of week 1 that is lecture number 4, we are going to discuss the well drilling methods. In earlier lecture, we discussed about the petroleum reserves and petroleum geology. It means how to identify the location where the drilling should be performed to get the potential reserves of oil and gas or drilling the well that can produce the reservoir fluid in the economical manner. So, drilling well is a complex process where many components are there. In this lecture, we briefly discuss about drilling methods, component of the drilling rigs, some component like drilling bit, casing, cementing, drilling fluid and briefly about the directional drilling concept.

So, drilling rigs that you can see in this picture is actually an integral system that is used to drill the holes in the earth's surface. Drill rigs can be a very massive structure housing many components in it. Primary purpose is to drill the holes for the water production, for the oil and for the natural gas. It can also be as small as like manually it can be moved.

That device is called the auger. If you correlate the drilling of oil and gas well with the water drilling that we had seen sometimes in our society or in our house, you can correlate how the drilling is performed for the oil and gas wells. The primary difference in that we need a massive structure to drill the oil and gas well because we are going to drill very deep several thousand feet depth and the geological formation is complex. Broadly, the drill rigs are classified in two parts like the operation those are done on the land we called it onshore rigs and those are done of the ocean side that we call the offshore rigs. On the offshore rigs if you see several arrangements can be done depending on at what depth the drilling is getting performed.

So, if the operation is in the shallow waters, the system is relatively simple and it is called the drilling wars. When we are drilling little deeper side up to 500 feet depth the jack up rig is used. When we are going to 10,000 deep in the ocean to drill the well the

semi-submersible system is used and the drill ship used when we are drilling up to 12,000 feet depth. So, there are different drilling methods that can be used to drill the hole in the earth surface depending on the formation geological location soil type different methods can be used. Commonly used drilling methods are percusion or the cable drilling, rotary drilling, dual wall reverse circulation drilling or the electro drilling.

These methods actually are classified based on the development. So, initially when the drilling started it was like percusion or the cable drilling then rotary component added into it and then more features were added to get the third type of the drilling methods. Most of the drilling process nowadays are done with the electro drilling even for the small application like for the water drilling purpose we are using the electro drilling system. Most of the wells are drilled vertical. So, the system that is shown here is for the vertical drilling system where the hole is created vertically.

For that purpose it is very important to identify the location of the reserves where we need to drill the wells and we are reaching to that depth. There are some other features of the drilling process that is directional drilling, horizontal drilling, multilateral drilling or creating the fractures in the earth surface. One by one we will discuss little bit about all of these methods. So, the percusion or the cable drilling it is a manual drilling operation in which a hammer bit is attached to a long cable that is lowered into the hole and then this technique is implemented by the back-and-forth motion that is loosening the soil in the borehole and that cutting are suspended in the water and removed to the surface. This technique is also known as cable drilling because the cable is used so it is like a simple method where the drill bit is actually loosening the soil and that soil is taking out from this hole to the surface by flowing the water.

At interval the bit is removed while the cutting are suspended in water which is then removed by pumping to the surface. Often steel casing is used that prevent the hole from collapsing down temporarily and also to protect the hole against the contamination of the groundwater. So, there might be a possibility there is a groundwater is nearby so the steel casing is used to protect the environment. This type of drilling is perfect for unconsolidated and consolidated formation like the sandstone or even the gravel but manual percusion can reach depth up to 25^{th} meters only that is very low value when we talk about the oil and gas well. Colonel Drake drug a first well in the United States that is up to the depth of 69 feet in 1859 using this cable tool percusion methods.

Then the next comes the cable that we inserted having the bit now this bit can be rotated and then the invention of the rotary drilling came in that way. In this method the digging up exploratory and the production well that can exceed up to the 5 miles below the ground. This equipment is having the tarec. Tarec is actually the assembly it is like a

crane that we see in the building construction sites where the crane is used to lift the heavy load horizontally and vertically similar we are having the tarec on this drilling rig platform along with the other component those are required to perform the drilling operation. The rotary table then direct the square callee which is connected to the drilling pipe.

So, callee is the assembly that is having the hole at the center and it allows the drilling pipes and the drilling string to go down in a controlled manner. So, the difference between the cable and the rotary here in the rotary we are having the rotary motion where the cable percusion it was just the bit that is hammering the soil and then we are getting the hole. So, the better features are in the rotary because it can drill up to the depth we want. In the rotary drill another feature was added that is dual wall reverse circulation drilling operation in which the pipes of concentric type are used to drill the holes. Drilling fluid is pumped through an outer sea well to reach the bottom of the weight and then recedes upward into the main pipe.

All cuttings are carried upward through an internal pipe and with the help of surface sea wells. So, this method is having the more advantage compared to the previous one. It is compatible with both rotary drilling and the percusion cable drilling methods. Fluid are circulated within a controlled space and all cuttings can be removed anytime. We do not need to wait like in the cable methods we need to take out the weight and then allowing the cuttings to come to the surface and then again inserting the bit to create the deeper holes.

This method is applicable for all type of the geological formation even the samples can be collected from the formation those can be analyzed in the laboratory. It allows for fast penetration in alluvial or the fissure rock samples. So, the next drilling is electro drilling. In this electro drilling the electric power is used to move the rotary part or the component of the drilling rigs. So, the rotary table winches and the callee are driven by the electric motor.

Thus, they provide the better flexibility in the operation along with the remote-control drilling. So, we do not need to be at the site itself even we can remotely control the operation. It provides direct power to the drill bit. So, the movement or the speed of the drill bit can be controlled effectively has been successful in complex geological formations, widely used to boost saving in energy and the material uses. So, the electro drilling is actually the successive progress in the drilling process where the electric energy is used to move the rotary component.

A big range of drill bit rotational speed can be achieved. Use different bore hole cleaning

agent in this process. One can even implement control drilling of deviated bore holes. It is not necessary we are doing the vertical drilling only because in the previous case it was either the manual in the cable case or in the rotary case we were rotating this thing the drill bit and we are going the vertically but with the inclusion of the electric power we can go to other direction drilling also. So, the directional drilling could be the horizontal well.

So, we are drilling vertical up to certain depth and then expanding the exploration in the horizontal direction also. So, with the help of the directional drilling we can go in the horizontal direction after certain depth. It is not necessary only one we can go in a multiple direction could be bilateral wells or could be multilateral wells. So, they offer certain advantage like within the single platform or with the single well up to certain depth we can explore more reasons to find the hydrocarbon fluid. So, the directional drilling is actually an extension of the rotary drilling techniques which guides the drill on a curved path.

So, already decided geologist already suggested where to drill we started drilling and then if the suggestion is to explore the nearby region directional drilling can help us to explore more reasons. Directional drilling can help oil explorer reach deposit that cannot be extracted by vertical drilling process. It reduces the cost as I mentioned just one platform can be used to explore the more area. Undersea reservoir we can use the computer guided automatic drilling machine to perform the directional drilling operation. Usually the depth of gas well is more than the oil wells.

So, when we are going the more deeper in the search of the gas well the directional drilling can help us because for example we are drilling up to certain depth and we are not getting crude oil or the natural gas. Then we can use some packers to seal this well and can start drilling from any certain length in the other direction like in the multilateral wells where we are having the search in the other direction. So, this kind of the directional drilling helps a lot to classify the successful well and the unsuccessful well. The operation of the drilling is complex depending on how much information is available about the geological formation. The geological formation where the drilling is going to be performed it is going to be the wild cat drilling.

It means like the area is not known much we just going to perform the drilling based on certain observation only or limited observation only. The success rate of the drilling well depends on like what kind of the geological formation we are going to drill. If it is a wild cat it is already producing field the success may vary. Long time back the success was one successful well nine dry wells when we are drilling the ten wells. Now the success is improved because of lot of the information is available still it is like one successful well

and two dry wells when we are drilling the three wells.

So, the ratio is in this manner. Drilling well is a costly affair to drill the wells more than a million dollar is required up to the depth of 7,000 feet. Of course, the cost vary at the locations and geological formation on average around 1.5 million dollar is required to drill one well. The component of the drilling processes the drill weight is one of the main component.

The drilling weight represent the head of the drilling string. Drill weight crosses the rock under the combined action of the weight of the drill weight and the rotational speed at which the drill is rotating inside the hole. Rotary weights are usually classified according to their design either they are the drag or the blade weights or the rotary cutter weights. So, the drag weights they work on the action of shear force include weights with steel cutter diamond weight and the poly crystalline diamond weights. Roller cutters or roller cone weights they use the action of crushing and chipping.

Tricones is the most common type. So, this kind of the tricones are created they are more effective to perform the drilling operation. In the pictures you can see there are different types of the drill bits are there. These are the simple drill bits you can correlate the drill bit operation we perform at home or any electrician or plumber perform to make the holes in the wall or the ground. These kinds of the drill bits are used. But when we are talking about the oil and gas drill bit process a large size of the drill bit is required or different size of the drill bits are required as we are going deeper the diameter of the drill bit reduce.

The important aspects of the drill bit selection is what kind of the geological formation this drill bit is going to dig. Diamond bits are effective because they are 40 to 50 times harder than the traditional steel bit. They are used to drill through the extremely hard rock surface. So, this kind of the operation where the extremely hard rocks are in the path of the drilling process the drilling bit is changed to diamond drilling bit and the operation is executed. Generally, the drill bits are made of force steel with tungsten carbides.

The second important feature is the drilling mud. Drilling mud actually a fluid that is either the air water or water with some additives that can be clay or bentonite or the other chemicals that change the viscosity and improve the heat transfer oil and synthetic fluid can also be used as a drilling mud. So, what is the operation of the drilling mud why it is important because when we are crushing the rock with the help of the drill bit the holes create the debris those debris need to be taken out to the surface drill bit itself get the hot when it is performing the drilling operation. And third important one is the pressure goes up when we are going down. So, the stability of the drilling operation is required and that

stability to the operation is provided by circulating the drilling mud.

So, the three major function of the drilling fluid is cooling the drilling bit, cleaning the holes and stabilizing the system. The fluid that is used could be the synthetic fluid they are pumped down the drill pipe and out through the pots or jet in the drill bit. Fluid flow up through the annular space between the holes and the drill pipes. So, in this operation what happens so the chosen drilling mud is circulated through the inner sides of the drilling pipes that reach to the bottom to the drilling bit it supplies the cooling effect. So, the drill bit is not getting hot it is circulated out come out from this the bottom of the drilling bit and circulated up through the annulus and take out the debris those are created by this drilling operation.

So, it is clean up the holes also or the bore holes. Three major component of this operation drill stem that is hollow turns the bit and posses fluid down annulus outside the stem where the mud comes up and the drill collar. So, this drill collar this part is having the more weight compared to the drilling string it pushed bit or the drilling bit down into the rock and the drilling operation is performed successfully. The choice of the drilling mud fluid depends on several factors. To circulate this drilling fluid to the system or to the bottom of the drill bit a circulating system is used.

The circulating system is a combination of certain units that is mud pumps, mud pit, mixing equipment and contaminated removal equipment. In this operation what happens so this is the mud pit where the mixing of the mud with the water or something to create the suspension fluid is prepared that is going to the mud pump. Mud pump is pressurizing this fluid to go to the annulus. So, from the steel tank to the mud pump the fluid is circulated from the pump through the high-pressure surface connection it reaches to the drilling string through the drilling string it reaches to the bit and through the nozzle of the bit and up the annular space between the drill string and the hole it comes to the surface. So, it is going down and then coming back when it is coming back it is going to the mud pit.

In the mud pit it is getting separated from the debris the contamination it is having during this process taking out the debris from the earth surface and the reservoir pit where this the debris are stored and the circulation of the drilling fluid mud is done again with the same process. So, the circulating system is required to circulate the drilling fluid mud into the operation. So, during the process of drilling another important is well casing. Casing is a large diameter pipe that is assembled and inserted into the recently drilled section of a borehole. So, when we are making the holes we start putting certain casing of different diameters the primary purpose of these casing is to seal the boreholes with cements preventing leakage and strengthening the holes.

The casing could be of different diameter as we are going deep the diameter get reduced. So, at the top it may be up to 36 inches while at the bottom up to 7 inches. So, the diameter is getting reduced to reduce the cost and the drilling operation is also done at the top it is a large size hole and slowly slowly the diameter of the holes is reduced to reach to a very deep position underneath the surface to produce the fluid. On the scale if you see here up to this is 1000 meters so this entire scale may be around 4 to 5000 meter. So, the casing arrangements are done in this drilling operation a typical well casing diameter or the dimension depends on the several factor.

So, with height or means width depth hole diameter is changing so the casing diameter will be changing and so the width dimension is also going to be changed that is going to perform the operation. Different layers of casing are installed during the drilling process first one could be the conductor casing. This conductor casing serves as a support during drilling operation. So, the conductor casing is here the first one the large diameter casing that is cemented with the ground it is providing a good support for the further drilling process. It may vary in the size that could be 18 to 30 inches or up to 36 inches in the diameter.

After that comes the surface casing this is utilized to isolate the holes from a fresh water that may be underneath the surface when we are drilling the holes water may come into the contact and then come to the surface through the bore holes. But if we install the surface casing it isolate that fresh water body from this drilling operation. The typical size of surface casing is 13th inch around then it comes the intermediate casing. Intermediate casing may be necessary on longer drilling intervals where the necessarily drilling mud weight to prevent blowout may cause a hydrostatic pressure that can fracture shallow or deeper formation. To stop that thing the intermediate casing are installed the casing placement is selected so that the hydraulic pressure of the drilling fluid remains at a pressure level that is between the formation pore pressure and the fracture pressure.

So, the fractures are not created by this circulating drilling mud. And at the end it comes the production casing or production tubing it is used for production purpose only it may be typically in the size of 7 inches. Production string is installed inside the last casing and tubing annulus is usually sealed or packed at the bottom with the help of the packer. So, for example, if this is the casing or production tubing the bottom section is packed with the packers and the holes are created around the section or certain part that is the length of the holes creation or the diameter is chosen based on the geological formation or the page on thickness. So, the holes are created with the help of some propellant and these holes allow the fluid to come to the production string and all the way through this production string it travels up to the surface where the production is captured it travels all

the way up to the surface.

So, the production string is the key component where the holes are created to let the fluid flow through this production string. There might be the situation when the fluids are not found in this region then it may be packed at the bottom and then another section can be chosen where the holes can be created or the process is called the perforation. Perforation can be performed to let the hydrocarbon fluids or the reservoir fluid travels from the reservoir region to the valvore regions. So, to create the holes up to certain depth drilling rig is used. Drilling rig is actually an integral system which house several components.

One of the pictures on here is having like around 24 components. There are many components important components are listed here and some of them are very funny words like the monkey boards, mouse hole, rat hole, dog house, blow out preventer is also required in this. So, all these features allow successful drilling in a safe manner and reaching to oil and gas reserves. Some of the key components I will be discussing in the next class. So, instead of going in detail of all of them let us discuss some of the key components.

So, the drilling component can also be classified as a power system, hosting system, fluid circulating system, rotary system, well control system and well monitoring system. Let us discuss some of key components like the crown block or the water table. This is the top most part in the direct. This is an assembly of the sieves or the pulleys mounted on beams at the top of the direct. So, the drilling line is run over the sieves down to the hosting drum.

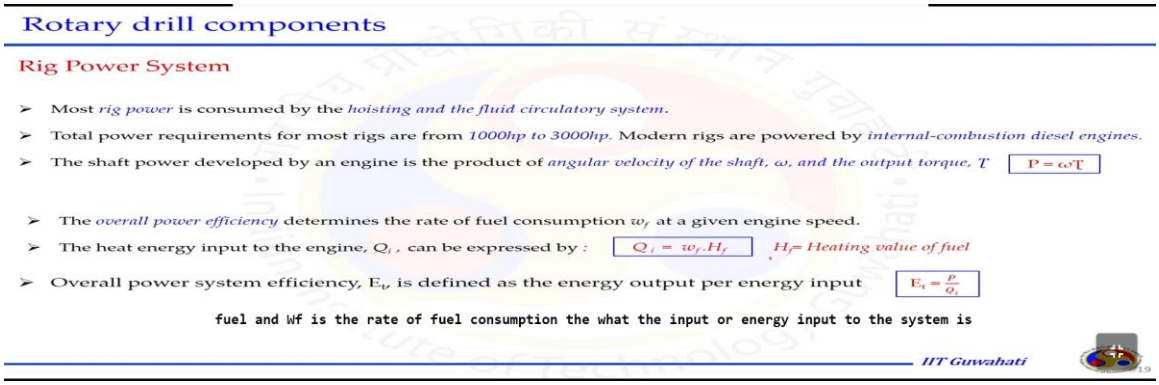
Mast, this is a portable direct system or a portable direct capable of being erected as a unit. So, this can be like erected as inventory cord. Monkey board, this is the direct mains working platform. Number 3 here, a monkey board located at a height in the direct or most equal to 2, 3 or 4 length of the pipe. So, the length of the pipe determine the positions of this monkey board.

It could be a different location the monkey board and in general it is at the 2 times of the length of the pipe, 3 times or the 4 times. Drilling rig component also include the travelling block and arrangement of pulley or sieves through which the drilling cable is reaved means move which moves up or down in the direct or mast. Dog house is a small enclosure on the rig floor used as an office for the driller or as a storehouse for small objects. Accumulator is a arrangement within the drilling rig system to store the nitrogen pressurization hydraulic fluid that is used in the rotary system that is also used to prevent the blowout happening in the system. So, what is this blowout preventer? A large wall that forms a seal in the annular space between the pipe and valve ore or if no pipe is there

just at the top of the valve ore itself is placed for preventing the blowout.

Electric house control system is also part of the rig system. Mud pumps, so very heavyduty circulating pumps are used to circulate the mud. Pipe ramps, the arrangement is made in such a manner like the pipes can be arranged on an angle ramp. So, it is easy to take them and then during the operation when they need to insert in the holes it becomes easy. So, the other components are important but we are not discussing them in detail. Rotary drill components as we classified in the group it could be the rig power system.

So, the most of the rigs consume the power by the hosting and the fluid circulation system. Within the rotary drill component there is a rig power system. So, most rig power is consumed by the hosting and the fluid circulating system. Total power requirement for most of the rig varies from 1000 horsepower to 3000 horsepower depending on the depth we are going to drill, at what rate the circulation of the drilling fluid needs to be performed and some other component.



Modern rigs are powered by internal combustion diesel engine. So, the shaft work developed by an engine is the product of the angular velocity of the shaft at what rate it is moving and the torque it is providing. So, the power could be W tau. The input power to the engine could be the fuel supplied and what is the heating value of that fuel. So, if hf is the heating value of the fuel and Wf is the rate of fuel consumption the what the input or energy input to the system is Qi. So, the overall efficiency of the power system can be calculated by energy output P that is omega tau and the energy input that is Qi.

Hosting system this is the picture that is showing about the assembly of the hosting system. The function of hosting system is to provide a means for lowering or raising drill string back and forth in the bore holes not only drilling string installing the casings and other subsurface equipment into and out of the hole. So, the movement of the string casing within the holes in and out is performed with this hosting system. The principal component of the hosting systems are the gyric the crane kind of this texture that can lift

the heavy weight the block and tackle that provide a mechanical advantage which permits easier handling of the large load. The example could be the crown block the travelling block or the drilling lines.

The draw works that is here that actually coils the large diameter drill strings. It provides the hosting and breaking power required to raise or lower the heavy strings of pipe. These include the component as drum, brakes, transmission and the CAD heads. Two routine drilling operation performed by the hosting system is making the connection of one pipe to the other pipe and making a trip. So, letting the string and casing going into the holes and when required back and forth motions or in and out motion of the drilling string is performed with this hosting system.

The rotary system we discussed little bit about the rotary component. The rotary system include all the component used to achieve bit rotations. So, the bit should be rotated and that is performed with the help of the rotary system. The main component of the rotary systems are Seawells, Callee, Rotary Drives, Rotary Table, Drill Pipes and Drill Collars. So, the Callee is here the Callee Busing that converts the rotation motion into the motion to the string.

So, the string goes down with the help of this Callee Busing or the Callee. So, this picture is showing about the Callee, Callee Busing, Rotary Table, Rotary Drives. So, the engine is giving the rotation motion that rotation motion is converted into the drilling upward and downward motion with the help of the Callee Busing and at the bottom side this is the drill pipes which is having the bit connected at the bottom and the bottom part of the drill bit is called the Drill Collar. So, the connection between the drill string and the drill bit it is with the very heavy weight section that is called the Drill Collars. So, the Drill Collars are thick balled heavy steel.

Tugular used to apply weight to the weight. So, the bit motion is happening in the vertical down direction only. Drilling pipes are provided in a different API length range. So, if the range is 1, 2, 3 according the length is classified for the range 1 the length could be 18 to 22 for range 2 it is 27 to 30 feet and the range 3 is 38 to 45 feet in the length. Rotary drill component also hosts the well control system. The well control system prevents the uncontrolled flow of formation fluid from the well bore.

The flow of formation fluid into the well in the presence of drilling fluid is called the cake. So, if the flow is not controlled it is happening in the uncontrolled manner suddenly because of the high pressure underneath the surface a kick may happen and then the blowout may happen. You can see here in this picture suddenly the everything is just blown out and the reservoir fluid started coming to the surface. Failure of well control

system result in an uncontrolled flow of formation fluid and it is called blowout. The flow of fluid from the well caused by a kick is stopped by the use of special pack of device called the blowout preventer or BOPs.

So, the BOPs are used to seal, control and monitor oil and gas wells to prevent the uncontrolled release of crude oil and or natural gas to the surface. These blowout preventers can be just a single device but usually they are put in the stack and that is why they call the BOP stack in the system. In general there are two types of the BOPs annular or the ram types. Annular BOPs are designed to shut off around any size and shape of equipment run through the holes. Both ram and annular BOPs are closed hydraulically with high pressure fluid accumulator.

So, they can be in the control language open or fully closed. So, when they are pressurized either they are getting the fully open or fully closed. That kind of the operation can be performed with the help of the high-pressure fluid. The accumulator that were having the nitrogen pressure cylinders at a very high pressure those can be used to perform the blowout preventers operation. The flexible annulus in the blue is forced into the drill pipe cavity by the hydraulic piston. So, the blue part in this moved in such a manner either it is getting fully open when it is pressurized or it is getting fully closed.

This blowout preventer is very massive device that is 50 feet in the size from bottom to top whose several components in it. So, the weight is also large. So, it is stopped any kick that is happening because of the unwanted things in the drilling process. So, the bell monitoring system safety and efficiency considerations are required to perform the safe operation that is required the constant monitoring of different components or safety features during the drilling process or even later on.

So, the device of bell monitoring system record or display several parameters. Those parameters could be the at what depth we are right now drilling during the drilling process at what depth the drill bit is at what penetration rate the drill bit is entering into the holes or creating the holes hook load rotary speeds of the drill bit at what torque is provided to rotate the drill weight pump rate pump pressure the density of the mud the temperature of the mud the salinity of the mud and some other features like mud flow rate and others. So, all these features along with the others features are continuously monitor during the drilling process to have the safe operation and this is also the part of the drill rig where the system is installed to monitor these parameters. Cementing and completion this is towards the end of the process at least cementing is done for the casing purpose in the initial time also. So, the cementing is performed by circulating cement slurry through the inside of the casing and out into the annulus through the casing shoe at the bottom of the casing string its need to be very precise the setting time the composition of the cement

slurry.

So, it is not blocking the inner section of the casing. For example, this is our surface the first casing conduction casing is installed this need to be cemented here for that purpose the cement slurry is circulated and that is moving through this annulus area and letting this casing to be fixed with the surface and similarly the other casing are also cemented with the ground that I said very precise calculation is required in terms of the cement is flowing through this inner hole and coming out through this annulus to seal it otherwise it may plug the inner part of the casing. So, once everything is done the drill valve goes to the completion stage. So, completion in the petroleum production it is the process of making a well ready for the production or for the injection if it is an injection well or generally at the early stage it is the production well that is completed and the process is called the well completion. So, in summary after exploratory drilling confirmation the presence of an oil or natural gas reserves the hydrocarbons are brought to the surface. So, when geologists suggest to drill the well at a particular location the depth formations are tested to perform the drilling operation the decision is taken based on the information available on the reservoir characteristic to complete the well production casing is installed and cemented and the drilling rig is dismantled and moved to the next site.

So, the job of the drilling rig is completed with the completion a service rig is brought to perform the production tubing along the down hole equipment. So, these are the post operations before the production start the installation of surface safety equipment takes place and the production begins. So, after performing the operation of the drilling rig the well completion is declared and the production start. So, in summary the drilling operations is performed the well completion is done and the well is ready to produce. This is the component of the production system that we see on the surface it is called the Christmas tree.

So, whatever is happening in the drilling process casing production tubing installation cementing that is happening underneath the surface on the top when we visit the field we see the component that is Christmas tree. This is the assembly of valve pressure gauge and choke fitted to the well head of the completed well the function of this Christmas tree is to prevent the release of oil and gas from an oil well into the environment it directly control the flow of formation fluids. So, the Christmas tree is having the safety feature it is having the monitoring feature it is having the control features for the productions. When the well is ready to produce oil and gas valves are opened and the release of the formation fluid is allowed through a piping that is leading to the refinery if it is crude oil that is getting produced it goes to the refinery if it is the natural gas well then the further surface facilities are available to refine the natural gas before it is going to the end consumer. These are some of the images of the offshore structures from the Bombay

high in the Arabian Sea installed by the ONGC.

So, some are fixed plate form and one of them is the floating structure that is actually producing the hydrocarbon fluid from these offshore reserves. So, in summary we discussed about the well drilling methods, component of the rotary drigs, drilling weight, circulating fluid that is mud, casing, installations, controlling and monitoring system those are required to have the safe operations. So far, we discuss about the petroleum reserves, petroleum geology and oil well drilling methods. So, with this I would like to end today's lecture.

In the next lecture we will discuss about the thermodynamics of hydrocarbon fluids. Thank you. Thank you very much. Thank you.