Surface Facilities for Oil and Gas Handling

Prof. Abdus Samad

Department of Ocean Engineering

IIT Madras

Well Completion

Good morning, ah today I will be starting the lecture on the well-completion upper part, and some other topics are there I will cover. So, one thing is that when you complete the lower part, the lower part means you have tubing, you have a casing, you have cemented, you have perforated that is done. There are different completion methods for lower parts, for example, open hole case tool or open hole you perforate, you produce and control in equipment ah. So, there are different ways. So, you know the people who are going into details of well completion and drilling will get details of that, but in our case, we are just giving a brief idea. So, that technical terms you should be familiar with.

So, one way is that you go through the lecture, another plus you go through ah extra material maybe Wikipedia, maybe Google search, maybe chart JPT. So, you should be familiar with the terms. So, whenever you will be using like say well completion, casing, cementing, or any other term you should not say ok I do not know the term. Whenever you are in petroleum engineering or you are learning petroleum engineering subjects, you should be familiar with the terms used in the petroleum industry.

Many times some terms can be used ah in the petroleum industry in certain ways, but common people will use the term differently. For example, rat hole mouse hole is okay though rat mouse terms people will understand some different ways, petroleum industry people will understand those are holes to keep pipes or Kellys. So, you must be familiar with the term. Then regarding units, I was told the field units should already be there. So, all industry uses specifically field units the terms barrel and ah gallon feet Fahrenheit Rankine all these terms also you must be familiar.

They use they will be using ah the term PSI pound per square inch instead of your Newton per meter square. So, you must be familiar with that PSI conversion also. So, whenever you are studying petroleum engineering you must be familiar with this term you have to be familiar with porosity, permeability, what is pressure, what is stress, what is fluid flow those are very common terms you are using. The petroleum industry means chemical

engineering, mechanical engineering, and fluid flow those things are a combination. ah Especially when you are talking about well completion, drilling, production, separation, and transportation which involves mechanical and chemical engineering.

So, you must be familiar with the specific terms, specific units, and specific definitions for example, pressure, force, temperature, pressure, ah units, relevant units, like someone saying barrel per day. So, you should not say I do not know ok. So, as a petroleum engineer, you must know. So, people will be expecting you also from you that you know the terms maybe many people will be asking you are petroleum engineer. So, do you know this one?

So, you should not say I do not know ok. So, you must be familiar with the general aspect of petroleum engineering as well as the technical aspect. So, a technical aspect we are giving here, but a general aspect you will get from Wikipedia, your Google search, your normal document, your news item regularly news item you will find that India is buying oil from this country, reducing this country, oil price going up, oil price going down, geopolitical issues are coming up because of oil in many countries and many countries want to invade them or ah there are lots of issues are there related to oil and gas because this is power energy. So, if you have energy you have power. So, there is a basic philosophy of all politics all over the world now at this moment.

Now, when you are talking about upper completion, upper completion will be included like wellhead you put ok ah then you put a casing ah Christmas tree again. So, if you tell common people Christmas tree. So, they will understand something different, but here oil industry will be assuming this is a controlling mechanism, a flow control mechanism ah through this one you can access your wellbore you have several valve arrangements there. So, the primary control valve, secondary control valve, safety equipment all things will be there in the Christmas tree.

So, this is not the actual Christmas tree used during Christmas on 25 December now there is mechanical equipment used in the oil industry and they will have a wet tree, dry tree, or only a tree sometimes they say.

So, those terms are there you must be familiar with, and again they will be putting choke here you can see. Choke also controls flow when you have continuous flow you are getting stable production. So, that time one choke will be there choke will flow how much upstream pressure will be there in wellbore how much pressure or how much flow rate you are accepting for your separation your production ok. And ah that is one important part of the oil industry because if you do not have choke then whatever flow you are getting you are producing. So, that can create an unstable production rate means if you have a sand control system and sand control system you have everything stable less amount of sand you are getting is produced no water injection water coning is happening, and suddenly if you change your production rate.

So, in that case, what will happen may be more sand will be coming into the wellbore or maybe water will happen. So, instead of oil and gas, you will get water more water and water is not economical you have to dispose also. So, if you are getting more water that means, you are in a danger zone your economy ah your profit level will be going down. So, you have to produce such a way that you can get less water into the wellbore you get more oil and gas.

Sand is also not economical because you have to dispose somewhere and sand will give corrosion erosion also if you have H2S then corrosion will occur again corrosion plus erosion will be more dangerous why dangerous because corrosion happens like a metal part because of corrosion, corrosion fluid this is metal iron H2S will be acting over it ok then it will be creating ferrous sulfate, ferrous sulfate.

Sulfate means it is softer than iron when softer than iron and you have sand particles heating sand particles will be trying to erode or remove the material and you have sand particles will get softer material iron salt is called salt right iron plus sulfide or sulfate. So, so This will create softer material softer metal will be removed quickly, and the corrosive fluid will get again fresh surface again. So, it will say I got a fresh surface I will act again. So, they will create salt again in metal heating. So, corrosion erosion will erode the system quickly.

So, that will be more dangerous if you have corrosive fluid and erosion also occurring. So, you have to prevent both actually if possible. So, sand you try to minimize you cannot stop 100 percent ok if you are stopping 100 percent sand production from the wellbore that means you are you have to stop the whole production. So, there will be some sand particles is very fine diameters that will be very low in the sand particle diameter. So, that will be coming with liquid oil or water and if you have corrosive gas.

So, many times you cannot avoid you have to accept it. So, in that case, you have to select material property properly. So, that it will not affect you so much in your systems, and can be deposited in your separator system pipeline system erosion will occur and suddenly if you are changing your production rate because of choke manipulation or you want to get more production tomorrow because oil prices rising. So, you get more production.

So, in that case, you are creating instability in your reservoir connectivity area reservoir connectivity area means that you have a wellbore and you have perforated right you have cased cemented then you have perforated perforated means you make lots of holes. So, that oil and gas will be entering into the wellbore and you will go to the surface ok. So, when you have this area this connectivity area will be like this I have a hole I have like long

connectivity perforations. So, there are lots of sand particles will be there which will create an arch. So, initially, you perforate I will explain later what is the perforation.

So, if perforate means you create a long hole long hole when you create lots of debris small sand particles or rock particles will be created. So, that particle will create a small arch. So, that will create a stable arch and you will get smooth production. Now suddenly you want to change your productivity. So, what will happen is this arch will get broken.

So, when the arch is getting broken the sand particle like this sort of arch is created. So, the sand will start coming in. So, this whole area will be unstable and you will get more sand. So, that is also not desired again many times suddenly you want to get more production. So, sometimes water will be there.

So, water will create some cones. So, oil and gas will not enter. So, rather water will be entering into the wellbore. So, you need stable production for a longer duration one year or two years ok? So, if you get less and less water you get the economic benefit, but if suddenly you change then your economy may get production today very high, but tomorrow it may not be very high it will create many other problems.

So, you must have a controlling valve because the controlling valve is required to control the flow you see any uncontrolled situation is there or even to access the wellbore. So, in that case through control valve control flow inject kill fluid I think those are not petroleum they may not be familiar with kill fluid means you create very high-density fluid injected in the wellbore so, that no oil and gas will come out from the wellbore to the surface so, when it is not coming out of the surface. So, that time you can do any piping cleaning or you can put in any artificial lift system because the reservoir has having certain pressure of less than 100 pressure pressure you create a column of high-density fluid h rho g if you have h rho g you can create the same reservoir pressure.

So, in that case, reservoir fluid will not be able to enter into the wellbore so, when it is not able to enter the wellbore. So, whatever work you want to do like say you want to remove one tubing or pipe want to put in the new pipe you want to put an artificial lifting system you want to put some valve beam mechanism anything it will be easy because no oil and gas coming out if oil and gas are coming out and you want to remove something it will very much difficult to handle because oil and gas can be dangerous it can fire source

right. So, you need to control the fluid. So, kill fluid means high-density fluid you are injecting into the wellbore.

So, that no fluid will be coming out the time you operate everything when the operation is done you change changing piping tubing and artificial lifting system anything after that you pump another fluid to remove the kill fluid density fluid has to remove then again reservoir pressure will be higher your tubing pressure lower. So, reservoir fluid high-pressure fluid will be coming into your low-pressure area and it will go to the surface, but if your tubing pressure is almost equal then there is no pressure difference no pressure difference means no flow. So, to fluid flow from one point to another point you need pressure difference. So, the wellbore bottom and reservoir pressure same no flow ok flowing pressure say flowing pressure and reservoir pressure are almost the same there is no flow, but if the reservoir pressure is higher then again fluid will enter and you will get production that is the main process. So, you will have lots of controlling valves there will be some subsurface valves also.

So, that will be a safety purpose. So, if something happens like say surface controls subsurface valve they say. So, in that case, what happens let us say anything happened some theft happened terrorism activities happened or something happened. So, in that case, oil and gas will be coming out because this Christmas tree will have lots of valves you can see their wing valve, So, many valves are their master valve primary secondary. So, just to control the flow by mistake something got broken or something happened.

So, in that case, fluid will be coming out continuously. So, if such a thing happens automatically the wellbore will sense that one ok something is wrong. So, immediately the flow will be cut ok using a certain automatic valve mechanism. So, that is called subsurface valve control from surface ok surface control subsurface valve that will be controlling the flow. So, that will be stopping the flow, ok this is called fail-safe operation you may have heard that train trains also have the same mechanism that says fail-safe if something fails in the train slowly it will stop if you cut one buggy's last 2 or 3 bogies.

So, bogies will be stopped it will not move because it is fail fail-safe operation if it is moving if it is fine driver is controlling things are fine, but if something goes wrong it will stop the flow. So, accidents and another environmental disasters will not happen environmental disaster means oil and gas if you go to your surface area then trees will be

their household and many many pollutions will be coming up. So, that will be more dangerous sometimes if it is offshore wellbore it is much more dangerous. So, because cleaning that oil spilling oil is very difficult to handle. So, many times in the US and Europe many time you say that fracking will not be allowed the government cases will be there.

So, fracking is a frack job they say frack job means a fracking operation that is called frack job F R A C the term sometimes they use F R A C job. So, sometimes the spelling will be also F R A C K I N G . So, you should both be correct many people use F R A C only frack job fracking ok? So, what is fracking? So, whenever you are working on oil in the oil industry. So, they will be using the term fracking or fracking job.

So, you drill a hole you put your casing and then you cement it ok. Now when if I have a reservoir here reservoir oil is there oil oil or gas or water may be there and I cement it. So, in one metal pipe, I put cement. So, there will be no inflow inflow means fluid is not entering into the wellbore and is not coming to the surface. So, then how to get the oil? So, you have to put lots of holes in the cemented area.

So, you put a pipe you put lots of holes how to put holes you have to go for a perforation mechanism I will discuss it later. Then many cases perforation only will not help in that case you have to crack the rock let us say you have oil and you have low permeability. You must be familiar with the term permeability porosity permeability porosity means you have pores or pockets where oil and gas are let us say these are pores ok? So, may be highly porous in this area, but this is not permeable permeable means these pores are not connected. So, if you drill a hole let us say I drill a hole here.

So, you drilled a hole, but lots of oil and gas are there, but the pores or pockets are not connected if not connected then pockets will not release in oil and gas. So, you will not get any production. So, what you have to do you have to create connectivity ok you have to create connectivity then pockets will be releasing oil and gas ok take my oil and gas. So, that is called permeability the connectivity ok. So, you must remember when you are working with oil and gas permeability porosity definition many times during interviews we ask what is the difference between porosity, permeability, and the unit.

So, you must remember. So, if a porous rock is there, but there is no connectivity. So, what will happen if you are not getting production? So, in that case, you go for cracking fracking ok how you crack this rock area will be there. So, you create very high pressure.

If you create very high pressure the rock will be cracked rock is there like this and it will be cracked when cracked fluid whatever is there will be entering into your wellbore.

If you create very high pressure from the surface surfaces rock will be cracked. So, fracturing you are fracturing using very high pressure this is called a frack job or fracturing job. So, those pores will be connected you will get more production. So, this is called hydraulic fracturing because using hydraulic fluid one fluid will be there you pump and you fracture and when you fracture again you release pressure you reduce pressure.

So, again this will be closed. So, when fractured and closed again you are not getting production actually because when oil and gas are moving they need some space. So, to create space sometimes they will be putting some sand particles they are called proppent ok. Hydrofracturing you put proppent or properly sized sand particle gravels ok. These you create like this cracking then you put lots of sand.

So, sand will create a porous area. So, fluid oil and gas will be moving through the sand pores, but they will not close completely. Let us say this is sand then it will be like this and it will open right. So, then you are getting connectivity. So, longer connectivity. So, the whole area hole is here, but the whole area area is broken.

So, that will be giving more oil and gas into your oil bore. Another way is acid fracking, acid fracking is when you fracture using a hydraulic mechanism then you put some acid. So, what will happen if fractured acid, acid reacts on surfaces when it is trying to close already reacted and remove material? So, automatically it will be created open.

So, it will not close completely because of acid erosion. So, normally carbonate reservoir if you have carbonate, carbonate reservoir you put HCl or many other chemicals acids are there you can put there and erode the surface itch the surface and although cracked is there removed material it tries to close, and it will open ok. So, some gaps will be there. So, that will allow fluid to flow. So, that is called hydro acid fracking. Another term is called matrix acidizing matrix acidizing.

This is called well well-stimulation technique. Well stimulation you created well and you are stimulating to get more production. So, in matrix acidizing what you do in your hydraulic fracturing is that much pressure is not required. You are injecting very high-

density strong acid when you put strong acid, acid will react with the carbonate reservoir on the rock. So, there will be eroding and this acid will be going like shape like this is well bore and acid will be moving like this there will be creating lots of branches.

So, that will matrix acidizing. So, that will create connectivity again when you are getting connectivity you are getting more production ok. You drill a hole after drilling you put cementing, and then again reservoir is not connected to your well bore this is a wellbore, right? So, it should be flowing through this and you will get production right. This is a reservoir where oil and gas is there. Now, there is no connectivity between the well bore and your reservoir.

So, you have to create connectivity one way you get cracking or hydrofracking then another is that you have to create a hole here because this is cemented in cement is there and a metal pipe is there. So, if cement and metal pipe do not there no holes or no pores the fluid whatever cracking or cracking you do fluid not enter into a well bore. So, many times you put one laser gun using a laser you burn this area, burn and you create a hole. So, that will perforation you create perforation, you are not breaking the rock you are perforating only. Previously you broke the rock, but here you are perforating only the laser or sometimes sand jet water jet.

So, many jet techniques are there one other way is that you put one gun like one pipe will be there and lots of explosive material will be there. So, using some electric wire from the surface you create an explosion here. So, the explosion will be such a directed. So, this explosion will be making holes on casing and cementing and it will be moving like this, it will create long long holes.

So, you got like this, this sort of hole you will get. So, this is called perforation. So, different techniques are there one will be laser-based, and there will be sand jet very high-pressure sand you can create and create jet and it will create a hole. Then you can create a gun perforation gun will be there ok? So, guns will be like RDX, TNT those sorts of materials the oil industry will be using and they will be perforating perfectly.

So, that way they will be creating connectivity. So, till you connect your wellbore to the reservoir properly your production rate will be lower because many reservoirs will have

low permeability porosity if lots of oil or gas is there, but not connected. So, what to do? So, you have to make the connection. So, you create hydrofracking or you create perforation. So, in that way, you are connecting the zone and you are getting more production. The sand control technique reduces the amount of sand you are producing.

So, already I told you that sand will have a negative effect because of erosion ok negative effect. One another is a deposition it will erode the surfaces and if corrosive fluid is there then corrosion also will be assisted right. It will assist corrosion like say corrosive fluid will get a new face every time a new surface and it will remove the salts again and give a fresh surface to the corrosive fluid. So, it will be increasing the corrosive corrosion rate or erosion rate or together you can see and deposition you have separated system it will get deposited you have other mechanical equipment horizontal pipe vertical pipe it will try to get deposited and it will be blocking the flow path.

So, that is also a negative side. So, you have to control sand. So, you can accept a certain amount of sand, but not a huge amount. So, you got the answer as to why you have to control sand. Now consolidated and consolidated formation. So, if you have an unconsolidated formation loose sand loose sand sand particles can move easily. So, in that case, you are getting more sand, but you have consolidated formation.

So, in that case, sand will not move so easily. So, you get less sand ok? So, first, you have to see whether it is a consolidated formation or an unconsolidated formation like a reservoir area whatever the rock is there may be very sand particles very strongly tightly fit moving another case may be sand particles moving easily. It moves easily which means you will get more sand It is called unconsolidated formation. Consolidated formation sand controlled not moving easily. Now if you have unconsolidated formation sometimes you inject the resin.

So, resin you inject at high pressure. So, resin will be entering into this uncontrolled unconsolidated area. So, the resin will bond the sands ok unconsolidated sand will be like this. So, the resin will create bonds ok? So, one sand to another sand will create some bondage. So, sand will not move easily. So, in many cases you inject resin you create bonding of sands. So, your sand movement will be lower, your life will be easier ok. In many cases, it is not possible. So, there will be different types or different techniques of sand control systems one is resin one is sand screen.

The sand screen is like this you have one pipe you make lots of slot holes. So, that way you are trying to reduce, but it still will give a certain amount of sand ok metal pipe it is called a slotted liner. Slotted liner means it is also metal pipe you have casing you have tubing you are creating metal pipe and you are giving lots of holes. So, it will reduce a certain amount of sand, but not so much effective. So, then the engineers thought let us make some different type. So, what they meant they meant different layers they say one layer is here one layer here in between they put lots of gravels gravel.

So, the gravel pack gravel packs one pipe is there put inside another pipe make lots of holes in the pipe in between the pipe you put lots of gravel or sand type of thing. So, you are creating a porous pipe two-layer porous pipe and your sand movement will be lower. Previously you had only one pipe you have lots of holes. So, the sand movement was easier now you create a two-layer pipe in between you put lots of gravel.

So, sand will be reduced, but again you are getting resistance you can see. So, two layers are there in between the gravel are there. So, whenever fluid from the reservoir comes to the wellbore it is getting resistant. So, your flow rate will be a little bit down ok. Now people thought let us say get much better quality.

So, they put a woven type sand control system. So, here like cloth type thing metal cloth, you can say. So, that will be reducing sand. So, that will be a much better sand control mechanism, but again it will be thinner also, but it will give more resistance also your flow rate also will go down. So, you get a very high-quality sand control system. That means high resistance you are giving and if you want to stop 100 percent sand means stop flow.

So, no production then there is no sand. So, if you want to get production some amount of sand will be there in many cases engineers will think ok let us take sand on the surface that case is also okay, but not all cases. In general, there will be some sand control mechanisms in a wellbore. So, you can get a limited amount of sand not very high you cannot stop everything ok? And regarding arch formation, I was talking about it like this like say arch sand particles are there, ok this is some hole is there in this is casing this is wellbore wall then the arch will be formed like this. So, slowly fluid will be entering and you are getting production ok it will go it will go to the surface fine.

Now, suddenly if you are changing your production rate what will happen this arch will get broken this arch will get broken when it is getting broken. So, again new arch will be

formed. So, till a new arch is formed you are getting sand production. That is why it should be tenderly cared for. slowly you have to change your production rate suddenly if you are changing then this arch will be broken you will get more sand.

So, sand will take the money it is not economical. So, you have to reduce actually. The next one ok production now you have wellbore cement cased casing is metal pipe you put you cemented right then you perforated ok you perforated then many cases you did some cracking also or cracking crack job we have done. Now, you are getting production you put wellhead Christmas tree you put choke also choke to control flow. So, the purpose is to control flow then after that you should have a separate system. So, whenever you are getting separated again during the good completion stage also many places or many wellbores will have artificial lifts especially gas lift systems wellbore offshore wellbore which will be put gas lift mandrel at the beginning of when they are completed because offshore operations are expensive.

So, they will put a gas lift mandrel at the beginning stage. So, maybe they will not be using it now the later stage they will, they will be putting a gas lift mandrel. So, the artificial lift there are several separate courses is there. So, I am not discussing the details of this one ok. So, we will move to the next class for separated system analysis and some fluid property analysis. Thank you very much for this class.