Natural Gas Engineering
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Module No # 05
Lecture No # 20
Review: Concluding Remarks

Hello everyone and welcome to the class of natural gas engineering again this is the final class of 20 hours lectures schedule.

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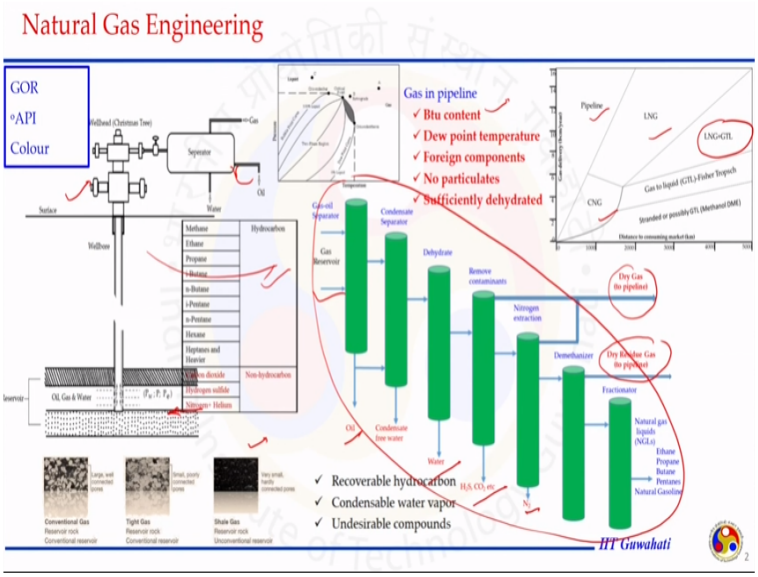

In this class we are going to review the aspects of natural gas production so we started our understanding of natural gas by understanding what is natural gas is what are the composition of natural gas and how natural gas properties can be estimated. We also understand how to estimate the reservoir properties and the properties of the reservoir those are important and appear in the discussion of natural gas engineering we understood how to estimate those like porosity, permeability, saturation and others.

Similarly the properties of natural gas like the density viscosity, critical temperature, critical pressure and others also discussed during the course. So in the first week we understood about the natural gas it is important and in second we understood about properties of natural

gas and the reservoir. We can review it quickly so the natural gas that is available underneath of the surface is supposed to be produced by drilling the well to that formation.

And once we drill the well the natural gas produces through this reservoir domain to well bore and from well bore to surface and at the surface we are having several units to process the natural gas. Once the natural gas is getting processed it produces oil remove the water some impurities like S2S, CO2 and N2 and some rare gases also can be separated out from this natural gas and ultimately what we get is a dry residue gas or the dry gas that is sent to pipeline.

We understood several terminology involved like that is dry gas? What is wet gas? What is residue gas and all those terminology having their own meaning at a specific location. After meeting the pipeline requirement like the BTU content natural gas should be containing that much energy the dew point temperature. So the natural gas should flow through the pipeline without having any problem removal of the foreign compounds no particulate matter and sufficiently dehydrated natural gas is sent to transportation we discuss several aspects of transportation also like the pipeline CNG, LNG, GTL and how to choose appropriate one.

We discuss in detail about the pipeline transportation we also discuss unconventional source of natural gas like the tide gas, shale gas, coal bed methane pyrolysis of oil shale in detail with the aim of understanding the pyrolysis of carbonaceous material. The recovery of hydro carbon condensable water vapor and undesirable products are important because they ultimately going to affect several aspects of natural gas business.

What is the value of natural gas what is energy content of natural gas how efficiently the transportation scheme can be adopted how much wear and tear happen in the system all will be regulated by this processing system how well we are going to refine the natural gas how well we are able to recover the valuable compounds those can be sold out separately. We also discussed here like at the well head condition we can calculate this gas to oil ratio and knowing this GOR the processing unit can be adjusted accordingly.

Specifically separator the separator should be designed to handle more oil or more gas similarly the other unit how much load is going to be on this process unit when we are producing specific GOR fluid from a particular reservoir.

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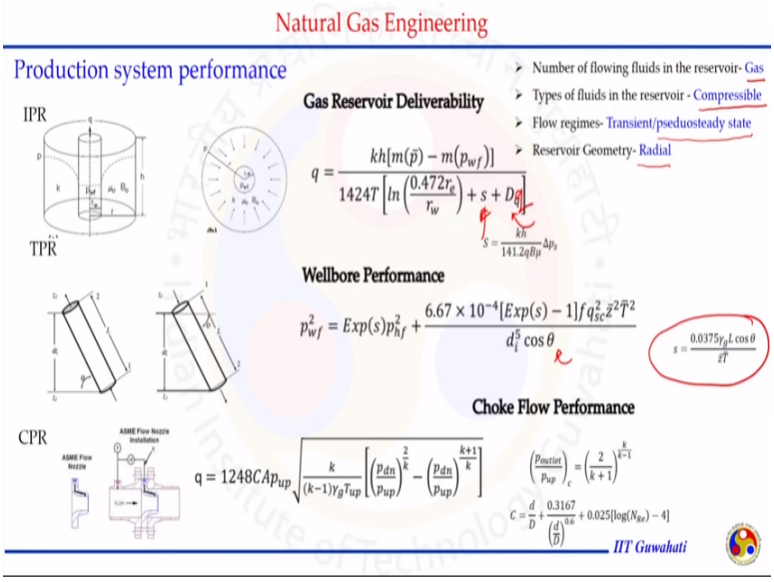

If we see in more detail what we did we classified the natural gas production system in three segment in B3 and B4 we discuss several aspects of natural gas production from the conventional reservoir. We classified that entire production zone in three parts IPR, TPR and CPR where in the IPR we could develop the relationship how natural gas is getting produced through a porous media where we are having the pressure difference as the driving force.

And the relationship established for Q versus pressure drawdown is having the properties of both reservoir as well as fluid and the other two parameters where also discussed in detail like skin factor and non-Darcy coefficient. When we were establishing the relationship we made certain assumption the assumption where like gas is flowing through the system gas is compressible by the natural and pseudo steady state was discuss in more detail compared to steady state and transient condition.

Because most of the time a gas reservoir is producing under pseudo steady state condition and we also assume the flow is happening under the radial condition. In TPR the flow through a vertical pipeline was discussed we had chosen and incline system and as the actual condition is the theta value can be adjusted to represent the vertical or horizontal pipeline system. In

most of the cases it is always vertical system through which the gas is being produced from PWF to PHF.

In this system also we could solve the equation by making certain assumption in CPR choke performance relationship we discuss about the sonic flow and subsonic flow conditions and further the relationship has been established how pressure drop across the restriction is going to control the production rate. We discussed critical pressure we discuss how critical pressure ratio can help us to choose appropriate set of critical equation to represent sonic flow or sub sonic flow condition.

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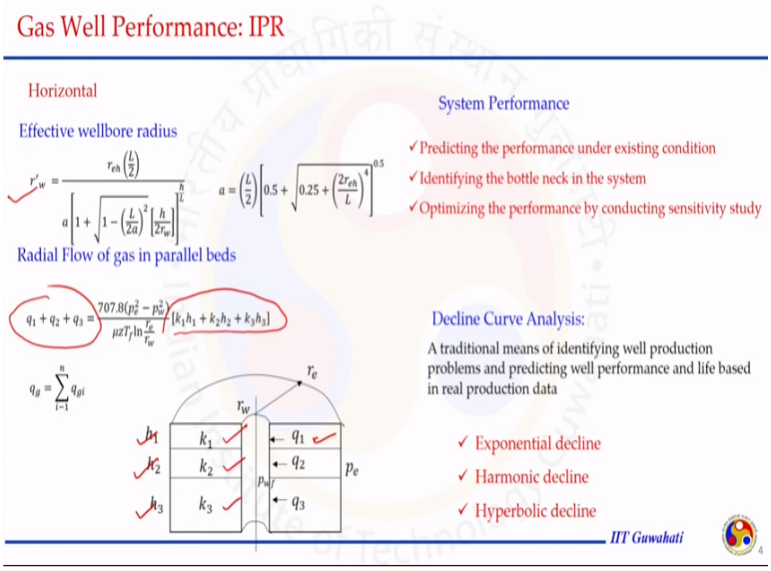

After establishing this three segment we also performed nodal analysis and in that nodal analysis we could understand how at a particular node the information can be obtained by eliminating some of the information. More complex system could be there like the flow is happening through horizontal pipeline system or the reservoir is drilled not only in vertical direction but also in the horizontal direction.

In that case effective well bore radius can be chosen and that is represented by the complex formula that says if we are replacing the radius by the effective well bore radius we will be able to get the similar expression. The radial flow of gas may be happen in a parallel bed so the well is drilled and perforation is done in a several zone and the flow of the natural gas is happening from several sector.

And those several sector are having different height H1, H2, H3 for simplicity just three bed were assumed they are different height H1, H2 and H3 they are having their own permeability K1, K2, K3 and the flow from individual bed is happening like Q1, Q2, Q3. So the overall production from such kind of the system can be obtained just for summing the flow rate on the right hand side we will see Q1H1 + Q2H2 + Q3H3 are added up.

We can do this for any N number of the bed those are responsible for the production for that the perforation is should be carefully maintained by understanding the IPR curve or the other expression involved in the production of natural gas a system performance analysis should be performed because the system performance analysis allow to predict the performance under existing condition.

So when a well is done we are able to set up the mathematical equation we are producing the gas from a particular gas well we can predict the performance by using those set up mathematical equation also under the existing condition. And if there is a mismatch between the condition either at the initial time or in the future we have to find out the bottle necks or the problem those are responsible for such kind of the changes.

For example the permeability we assume certain value to perform the mathematical analysis to prediction or the assumption of permeability may not be accurate enough we have to play around the variable to adjust our mathematical equation. After identifying those key factor that could be either the permeability as I mentioned could be this skin deposition happen over the time or could be we are assuming it is Darcy flow is happening while it is a non-Darcy flow in the near well bore reason.

It may be because of the liquid loading is happening in the system or may be some other reasons we have to find out those bottle necks and after knowing those we can perform the sensitivity analysis about those parameter and can optimize our system and that can be done by performing the system analysis. The parameter could be the tubing diameter could be the permeability could be any variable or parameter is appearing in the mathematical expression of IPR, TPR and WPR.

Another method of understand the system for future forecasting is decline curve analysis it is a traditional method for identifying well production problems and prediction well performance and it is life based in real production data. So such kind of analysis the production data are recorded and the rate data are plotted in systematic manner to understand how the production rate is declining it is happening in the exponential manner, harmonic manner or hyperbolic manner.

Understanding this behavior will tell us how the natural gas reservoir or particular well is going to behave or perform in future accordingly the business can be setup.

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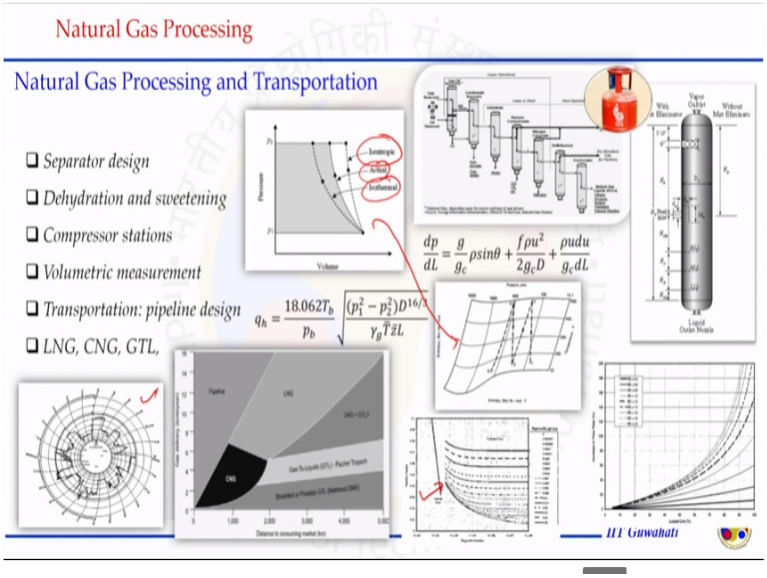

In the second part we had considered natural gas processing starting from the first unit itself that is the separator. We discuss why separator is important how separator does work how many types of separator are there and the design of the separator for both horizontal and vertical. We consider only the gravity separator in detail and understood the working principle including the flash calculation.

Further going out in the processing units we had discussed briefly about the other units but in detail about the dehydration and sweetening process. So in dehydration we had discuss the processes like cooling, compression followed by cooling absorption and adsorption process to remove the water similarly for the sweetening processes also we had discuss the processes based on the absorption, adsorption or direct conversion of H2S2 elemental sulfur.

For the compressor stations we had discussion in detail about how compressor does work in which mode it should be operated to get the most work done on the transportation or transporting the natural gas. We had discussed how to calculate the work done under the isentropic condition isothermal condition and under the actual conditions. We also discuss Mollier diagram how it can be useful to calculate the work or energy required to operate or compressor from particular pressure P1 to P2.

In the next volumetric measurement we had discussed several ways of volumetric measurement in details we had discussed about the head measurement devices or specifically the orifice meter the several correction factors those should be implemented in the orifice meter equation to have the accuracy in the measurement. We also discussed some old methods like the chart method where we can predict the flow rate of the natural gas using this kind of the chart.

In transportation we discussed some of the aspects of the natural gas transportation but in detail we had set up the mathematical equation for transportation of natural gas through the pipeline and in that design concept we started from the first law of thermodynamics and based on how we are going to calculate the value of friction factor either by the Moody chart or how this friction factor related to Reynolds number as well as on the roughness of the pipe.

We had discussed in detail three set of the equation Weymouth equation, Panhandle A equation, Panhandle B equation and the generalize formula for representing the these three equations. We could also establish the processors where a quick calculation can be done in terms of how pipeline is layed out in a series pedler or loop manor.

So if a particular pipeline is given to us and to increase the throw port or the transportation rate through that pipeline we can install either the series with the bigger diameter or a pedler or in a loop manor that we were discussed in detail. Then we also discuss about other form of the transportation of natural gas like LNG, CNG and GTL.

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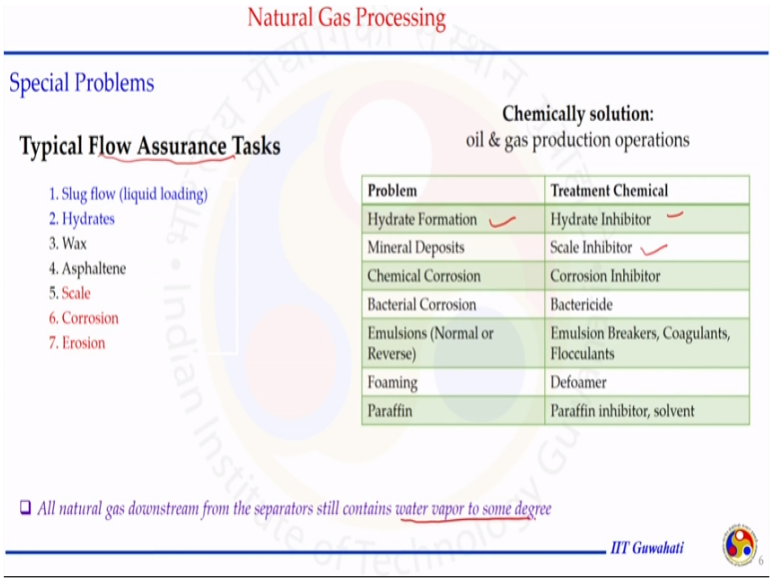

So when we are dealing with the natural gas from its identification to its transportation. Several issues comes is specifically during the production and transportation when we are flowing the natural gas through a pipeline because of other component like the water higher hydro carbons inert gases non-hydro carbon gases several problem appears in this system and the problems are under the head of flow assurance in the oil and gas industry.

The problem could be less flow it is a liquid loading when we are having the two phase system depend on the superficial velocity of the gas phase and liquid phase there might be different patterns as we discuss previous classes there could be slush flow there could be endless flow there could be other type of the flow depend on the inclination the pipeline is having it is a vertical it is horizontal it is at a particular angle.

But the slush flow liquid loading happens the gas is not having enough energy to transport the liquid or to remove the liquid from the pipeline or to carry over the liquid or to the next destination. How to avoid the liquid loading issue? Similarly how to prevent hydrate formation in the system where discussed briefly. There could be other method also to prevent these issues like using the chemical solutions.

So oil and gas in industries several chemicals are used to specific problem so for example for hydrate formation hydrate Inhibitors are used for mineral deposition the scale Inhibitor are used chemical corrosion, corrosion inhibitors are used and similarly for the others. This

happens because whatever the level of treatment of processing be performed there is always small amount of the water and light hydro carbons will be in the natural gas and that is where we have to either use chemical solutions or some means to clean the pipeline.

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To clean the pipeline a device called pig, PIG that is stand for pipeline inspection gauge is used and that that is having it is all role initially it was used just to clean the pipeline later on it has been modify to use not only to clean the pipeline but also act as a monitor gauge where we can understand what is happening in the pipeline like the wall thickness is getting reduce anything getting deposit so we can just put some sensor on it and when the pigging is being done.

We are also able to understand the situation of the pipeline in broadly the pig units are divided in three parts utility pigs. These are used to perform cleaning separation and dewatering. Inline inspection tool to monitor pipeline and to the extent and location of any problem that is going to be in the pipeline or that is happening in the pipeline. Gel pigs using conjunction with conventional pig to optimize pipeline dewatering and cleaning.

So we can see from these picture is the hydrate formation is happening it is blocking entire pipeline and this is no more useful we have to take it out cut it and replace it. Or we can do with a very specialize pigging or periodically pigging it and we are able maintain the dewatering cleaning and the pipeline for it is effective uses.

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So with this I would like to thank you all for watching the videos of natural gas engineering course and I say good luck for the exam you are having a head. I hope you enjoyed the content and the structure of the course design for 20 hours lecture schedule my contact detail is here you can contact me related to any issue of this subject specifically assignment problems and the exams thank you very much.