Upstream LNG Technology
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Lecture – 41
Dehydration of natural gas

Welcome. After learning the basics of the various processes involved in the natural gas processing like heat transfer, fluid mechanics, mass transfer, etcetera. Now, we shall go to the actual processes and one of them is dehydration this dehydrate.

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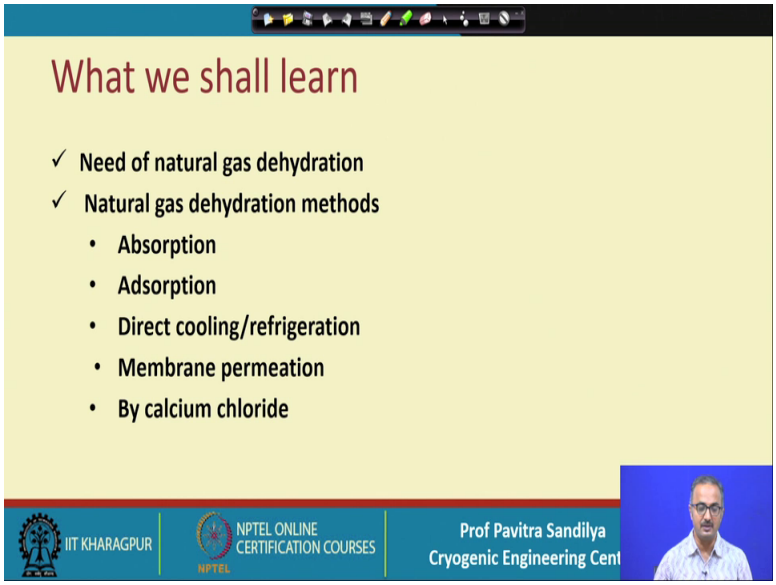

This particular lecture will be devoted to dehydration of natural gas and in this particular lecture, we shall be learning about the need for gas dehydration and the natural gas um dehydration methods like absorption, adsorption, direct cooling, membrane separation and use of calcium chloride.

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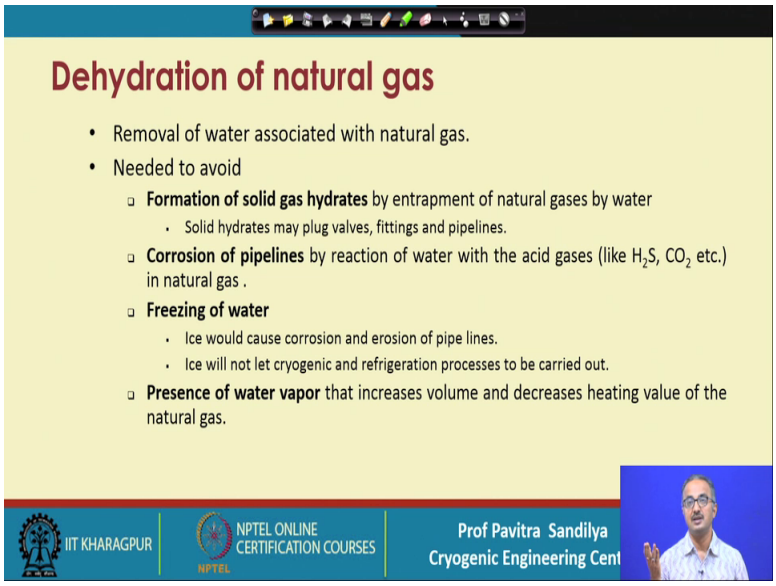

So, these are some representative methods to dehydrate the natural gas. So, first let us see that why do we need to dehydrate natural gas, there are some various reasons for that; one may be that we want to avoid the formation of the gas hydrates which are formed when water and kind of adsorbs or water captures some kind of gases like methane, ethane, etcetera or carbon dioxide present in the natural gas and it will form some kind of solid which is looks like ice.

So, this hydrates when they formed, they can choke the plug, valves, fittings and pipeline and water can also react with the acid gases like H2S, CO2, etcetera and can corrode the various pipelines and the equipment, then water itself can freeze and form ice and these ice can cause erosion and corrosion of the pipelines and if we are carrying out some kind of cryogenic process while during the liquefaction of natural gas, this will be difficult to carryout in a presence of water because water will freeze and will choke the pipelines.

And presence of water vapor also increases the volume of the natural gas and also reduces the calorific value or the heating value of the natural gas. So, these are some of the reasons for which we need to dehydrate or remove water from the natural gas.

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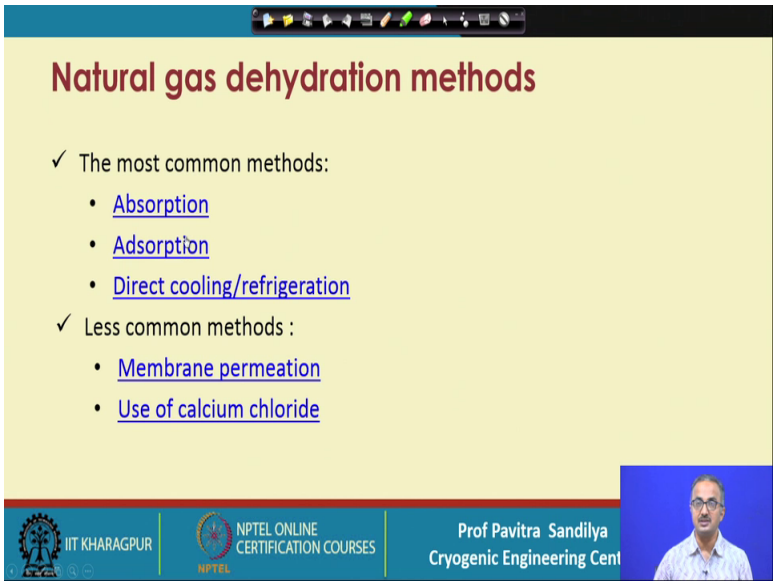

Here are some common methods which are used for the dehydration, absorption, adsorption, direct cooling or refrigeration and we have some less common methods are been developed that is membranes permeation and use of calcium chloride.

These methods membrane permeation is also being researched upon and it is also being developed, but for the time being we are more concerned with the absorption adsorption and direct cooling. So, let us see one by one each of this processes.

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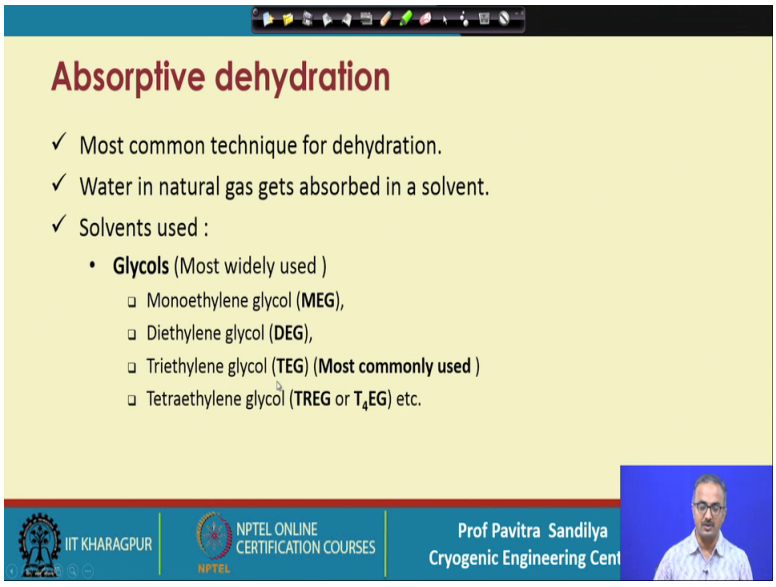

So, in absorption; what we do that it is very common process and it is the water is removed by absorbing in some kind of a solvent and the solvents used in this industry are glycols we have monoethylene glycol, diethylene glycol triehylene glycol and tetraethylene glycol; these are some of the commonly used solvents to remove water.

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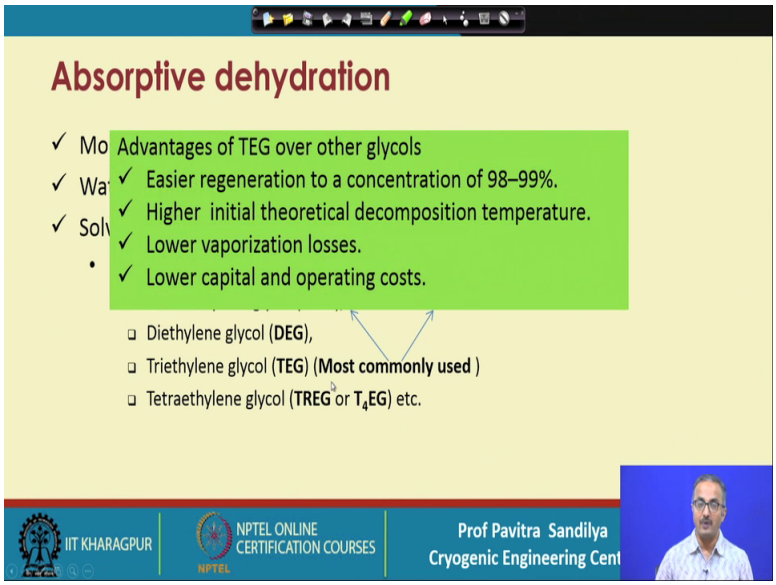

And among this triehylene glycol or which we call TEG is most common and why because among all the glycols is it is easier to regenerate, this glycol this glycols are regenerated by passing steam over them. So, it is easy to regenerate this TEG and we can get only about 98-99 percent of the TEG after regeneration and it has higher theoretical decomposition temperature, we warn that the solvent should not decompose at high temperatures.

So, TEG are very high temperature for its decomposition that is it is quite stable and then it has low vaporization process, it means it will not vaporize easily into natural gas thereby, it will reduce the chances of contamination of the natural gas by itself and it has quite low capital and the operating costs.

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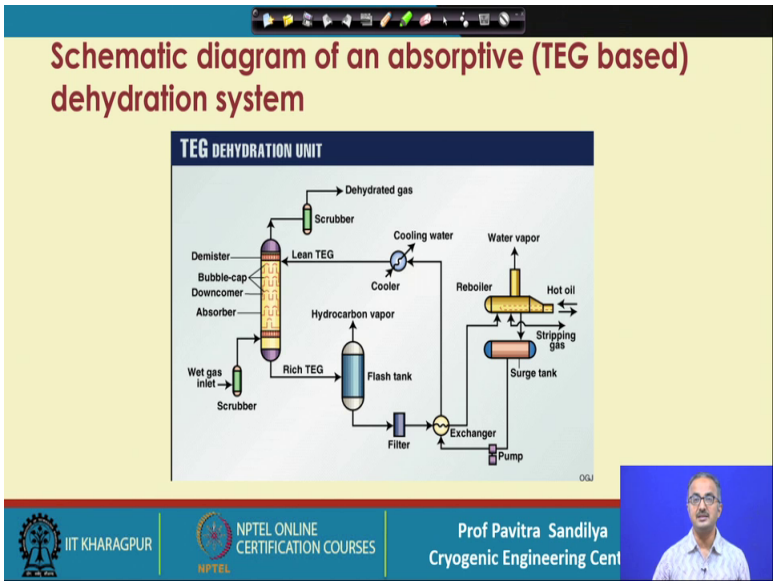

And here is a typical representation of absorption of a water by TEG, here we find the wet gas; wet gas means natural gas with water is coming through a scrubber in the scrubber, we are removing all the particulate matters and then it goes to this column which we call demister in this we have contacting this with the TEG, we calling lean TEG lean means which has a less amount of a water.

And then it goes down and this gas moves up this buoyancy and then what happens at the water we are getting rich TEG rich TEG means it is now having lots of water with it and this is getting flashed and we learned about flash earlier. So, we can see that applications of various types of processes process and fundamentals which we learnt earlier in this various processing of the natural gas.

So, we did flash calculation earlier. So, here we find that by flash the hydrocarbon vapors are taken out and we get these rich TEG further and then it is pass through some exchanger and here, we are passing it through some oil to get back the TEG and ultimately, we are putting the lean TEG and again putting it back to the column, whereas, this gas goes out of the column with reduced amount of water and we call it dehydrated gas.

So, this is the overall representation of the dehydration process.

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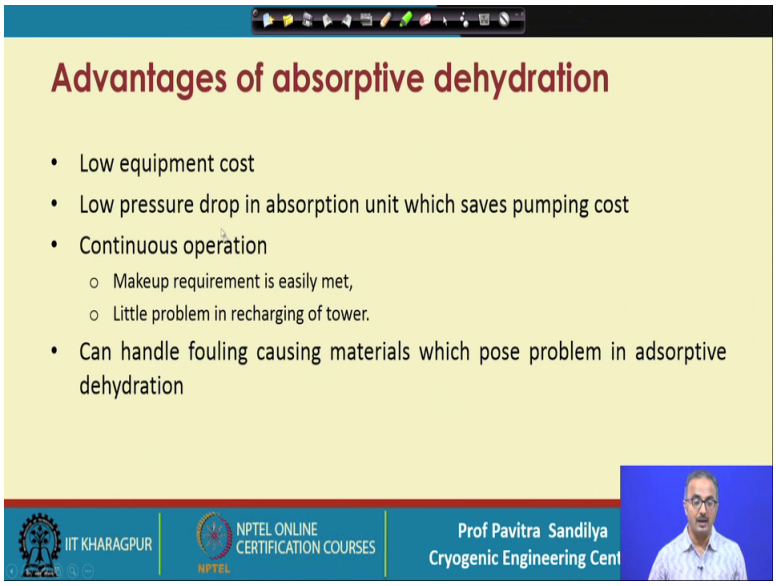

And the advantages of this absorptive dehydration processes are that it has a low equipment cost, it offers less pressure drop and that pressure drop translates into the pumping costs. So, we are reducing the pumping cost also and it is a continuous operation; that means, we do not need to make up the loss because we are not losing much of the TEG we are able to remove recover almost 98-99 percent of TEGs.

So, we do not need to put too much of makeup TEG in the system or the solvent in the system and we have little problem in recharging of the tower and it can handle fouling can handle fouling by causing materials like which pose problem in the adsorptive dehydration. So, we are reducing the chances of fouling.

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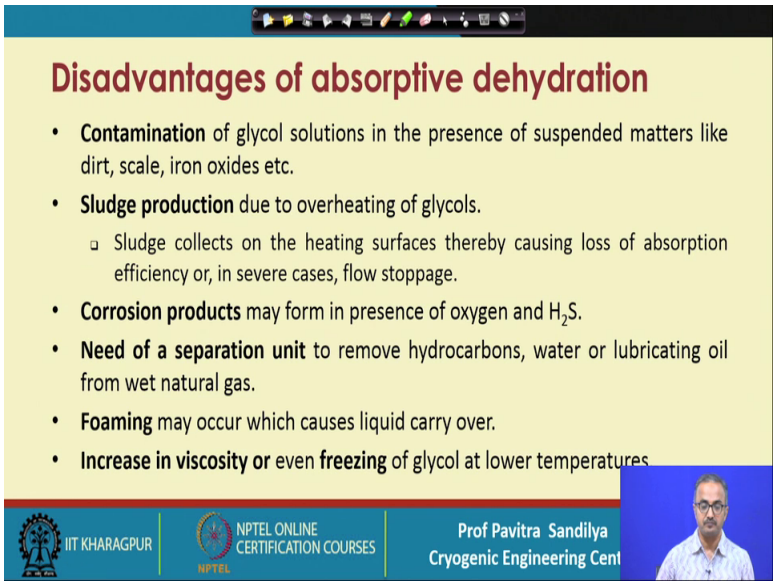

But it has some disadvantages also like the glycol solutions may get contaminated by some suspended matters like iron oxides that is by rusting if there is some rusting, the iron oxide will come from there the scale formation and dirt etcetera they can contaminate the glycols, then there could be sludge formation when the glycols get overheated.

And these sludges will get collected on the surfaces of the various equipments and in then we also cause some kind of stoppage of the flow and also they will reduce the proper contact between the solvent and the gas. So, that that way they will reduce the efficiency of dehydration, then they may form some corrosion products by reacting with oxygen and hydrogen sulfide, then they need some separation unit to remove hydrocarbons water and lubricating oil from natural gas otherwise these will react with the glycols.

It can cause foaming and when there is a lots of foam; what will happen that they will carry over the liquid the gas will be carrying over the liquid along with it. So, we loss of this material and increase in the viscosity or even freezing of glycol at lower temperatures; that means, that means that glycol may freeze at lower temperatures.

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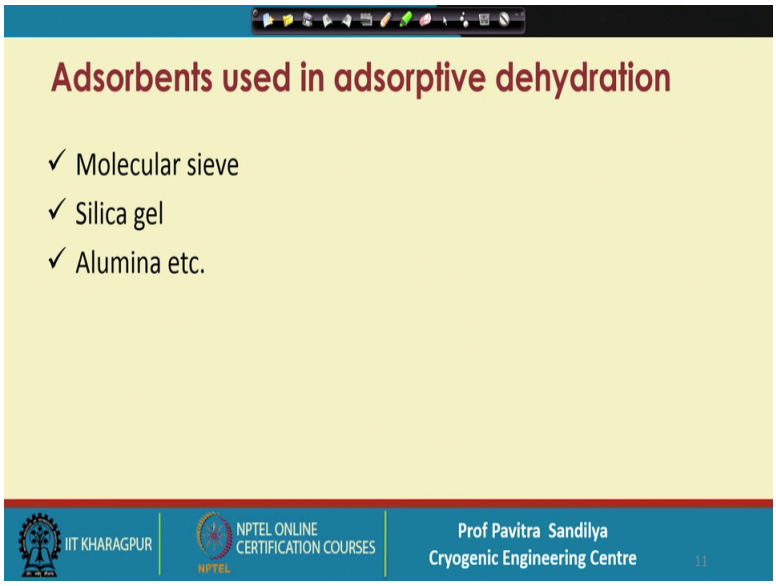

Now, we go to the another thing at the adsorption in the adsorption, we have the various types of absorbents which are used like molecular sieve, silica gel alumina, etcetera.

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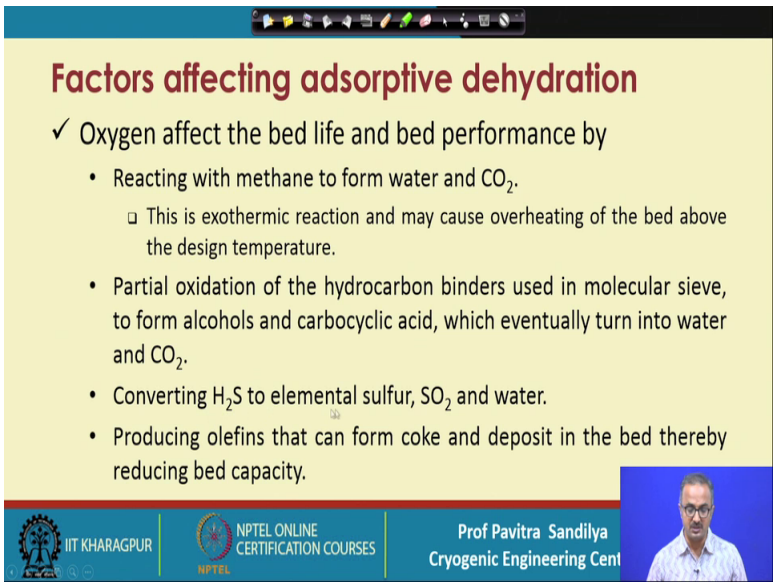

And these are the factors and there is it is affected by the oxygen and how oxygen can react with the methane to form water and carbon dioxide and this is an exothermic reaction which causes the overheating of the bed above the design temperature and if it is overheating then what happens that the instead of absorption the things get the solutes will get desorbed.

That means we will not be able to achieve the desired dehydration due to this overheating of the bed then the hydrocarbon binders which are there in the molecular sieve get partially oxidized in the presence of oxygen. So, we have to make sure there is no oxygen in the system and once this get hydro this molecular sieve get partially oxidized; what we will find that they will form alcohol and carboxylic acid which will turned into water and carbon dioxide.

And then this oxygen can also convert the H2S into elemental sulfur, sulfur dioxide and water and then it can produce olefins that can form coke and deposit in the bed and if they deposit on the bed what will happen they will choke the bed and thereby, they will reduce the capacity of adsorption.

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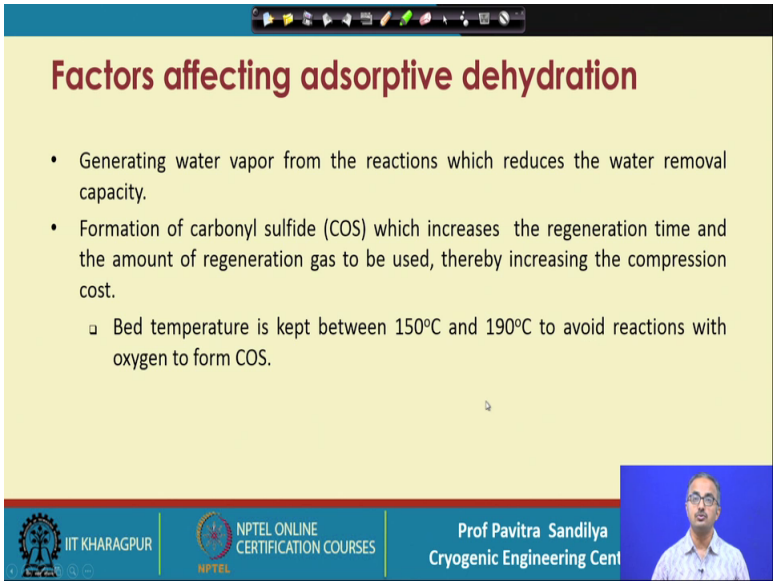

Water will also generate water vapor, then it reacts my with the other hydrocarbons and this will this will cause a reduction in the water removal capacity by generating extra water due to the reactions and it can form some kind of carbonyl sulfide which will increasing the regeneration time and the amount of re regeneration gas to be used for regeneration.

And this will increase the cost of compression of the gas and the bed temperature should be kept between this 2 temperatures 150 and 190 degree centigrade to avoid any kind of reaction with this carbonyl sulfide.

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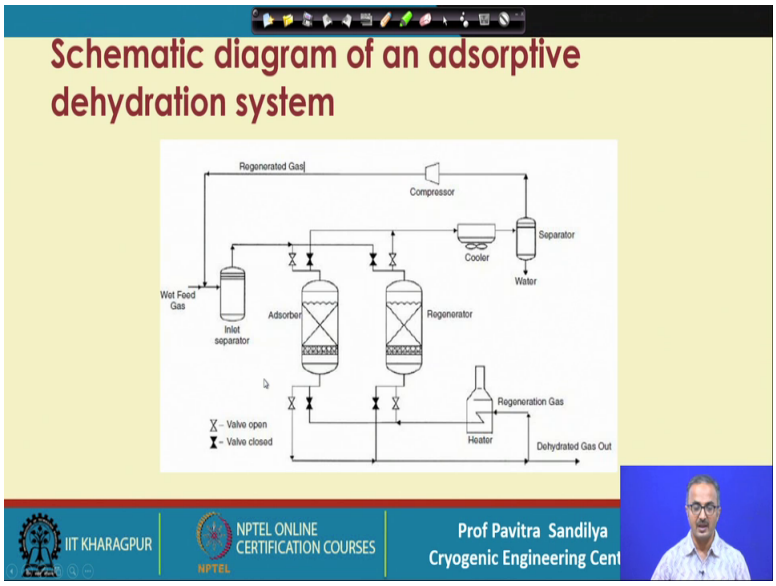

And here it is a typical adsorption system for dehydration here, we will find we are having 2 absorbers, here we have the wet feed gas which is coming through some inlet separator and the one of this beds will be undergoing adsorption and the other one will go for regeneration; that means, we can say that the wet gas come, suppose, it comes to the first bed and then it goes out dehydrated gas.

And this black ones represent the valve is closed. So, initially we find when it goes from here this valve is closed. So, this particular bed is under regeneration. So, once this particular bed gets saturated then these valves get closed and this valve opens. So, now, the gas go and it will come from this bed. So, this is the way that alternately these 2 beds are undergoing either adsorption or regeneration and then we have the compressor; compressor and the cooler to compress the gas and this is how we are able to get the dehydrated gas from the adsorption system.

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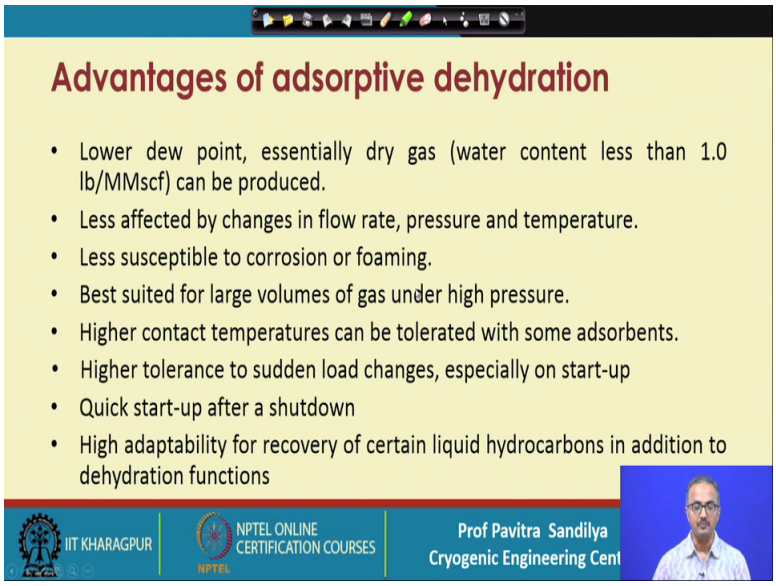

Now, let us look into the advantages of the adsorptive dehydration, we find that there are lower dew point and we learnt that dew point is a representation of the water content of the natural gas. So, lower the dew point means we have a less amount of water. So, they can give a better dehydration for the natural gas and they are less affective by changes in the flow rate pressure and temperature.

And they are less susceptible to corrosion or foaming and which one the case with the solvents. So, solvents can foam, but this is not foaming and the best suited for large volumes of gas under high pressure, they have a higher contact temperatures maybe tolerated with some adsorbent without getting destruction of the adsorbents; that means, destruction will in terms of their chemical nature or physical.

So, they cannot get destroyed by a higher temperature some of them cannot can withstand the high temperature and they have a high tolerance to sudden load changes, especially, due to the startup if there is a sudden there is a change in the flow rate of the feed natural gas, they can still sustain the operation without sacrificing their performance.

They can get quickly started up after a shutdown and they have a high adaptability to a some hydrocarbons in addition to dehydration functions.

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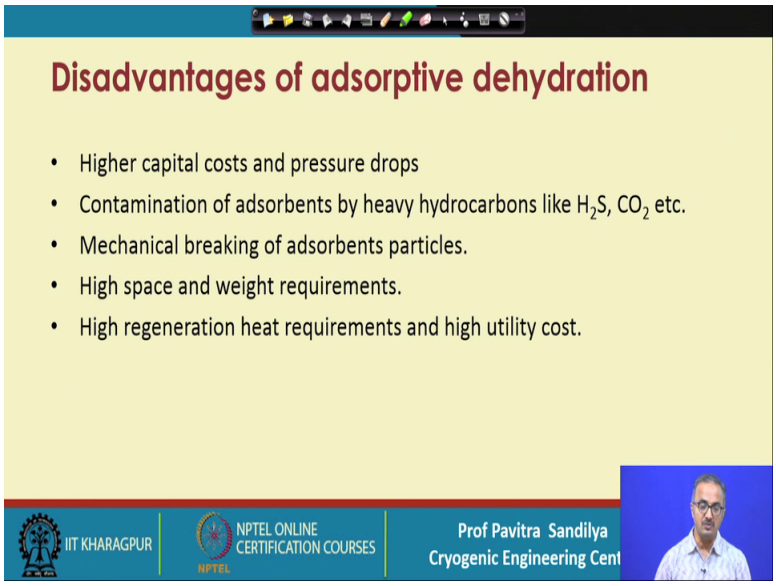

They have some disadvantages also like their capital cost are high they also result in higher pressure drop they can get contaminated by heavy hydrocarbons like H2S non hydrocarbons like H2S, CO2 and they can undergo mechanical breaking due to the attrition they need high space for their accommodation and that is how they increase the weight of the system and then they have a high regeneration requirement for and ah; that means, you the heat requirement or the energy requirement for the regeneration is higher for this adsorbents.

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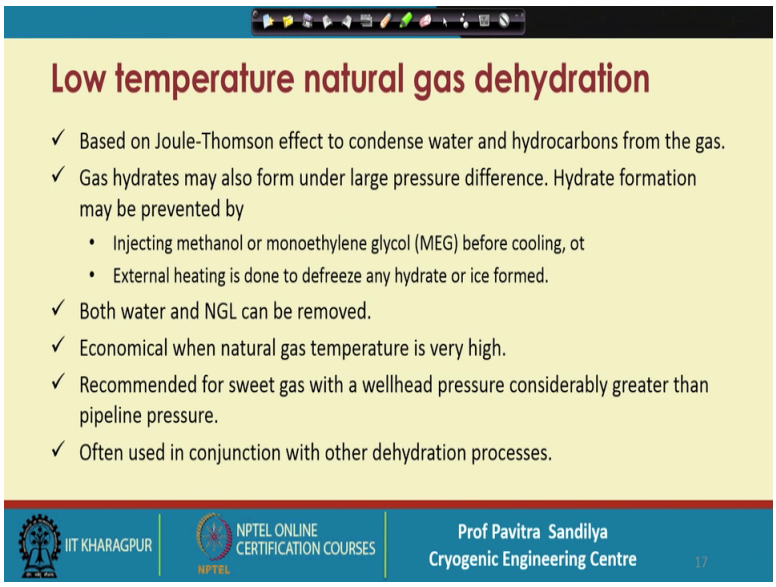

Now we come to the direct cooling or refrigeration in this case what we find that there is a Joule-Thomson effect. So, Joule-Thomson effect is an effect which is found when we pass some gas through a valve and what we find that on expansion at the on the downstream of the valve, there can be a reduction in the temperature of the gas and this particular effect is called Joule-Thomson effect after the name of the two scientists who invented this particular phenomenon.

So, this Joule-Thomson effect ah] is the basis of cooling the natural gas and when this effect happens that the temperature is lowered and that is how the water vapor can get condensed out from the natural gas , but in this case what could happen that gas hybrids may get formed and as we learned that gas hydrate formation we will be having a bad effect on the process because they will choke the system and to reduce the formation of the gas hydrate; what we can do that we can injects some of the glycols which were using for absorbing water and. So, the, this gas hydrate gets destabilized. So, they will not be formed and other thing is that we externally heat the system to destroy this hydrates.

So, these are the things we have to do if we find that is too much of cooling and water is going towards solidification and by this low temperature dehydration one can remove both the water and the natural gas liquids that is NGL about which we shall learn later on and this is economical when natural gas temperature is very high and it is recommended for sweet gas with a wellhead pressure considerably greater than pipeline because when the pressure is very high, then on this Joule-Thomson expansion we get higher cooling.

So, the high pressure is desirable on the upstream of the Joule-Thomson valve. So, in that way, we find that if the initial pressure of the natural gas is high, then this works very efficiently and this is often used not with alone, but in conjunction with the other dehydration processers like with solvents or adsorption, we use this low temperature method.

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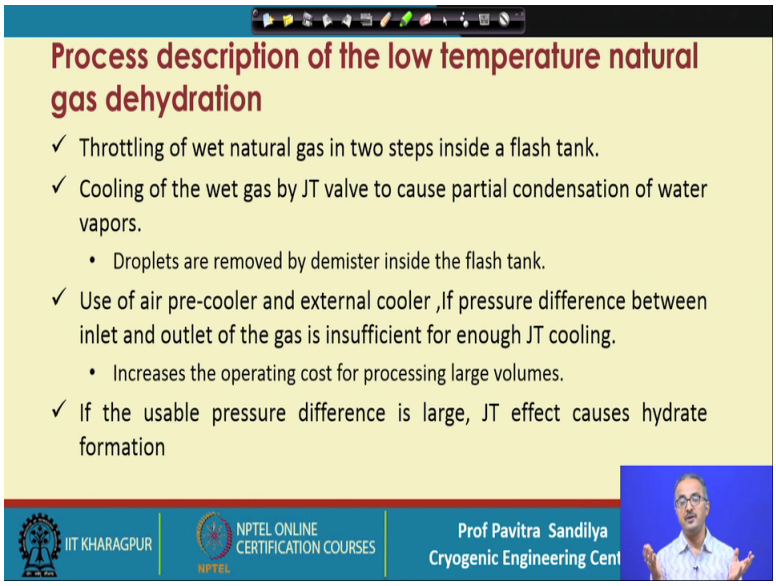

Now, here we have the process description; what we first do? We throttle the wet natural gas in 2 steps and when we do it with this Joule-Thomson valve, it causes partial condensation of water vapor and the droplets are removed by demister inside the flash tank and then we use some air pre cooler and some external cooler, if there we find that the pressure difference is in sufficient to cause enough cooling of the by JT valve.

And when we are using this pre cooler or external cooler to compensate for the reduced cooling by the JT valve; what we are essentially doing we are increasing the operating cost of the processing. So, for if the usable pressure difference is large, then JT causes; that means, as I told you that if we have a very large pressure difference between the inlet and outlet of the JT valve, we will find there will be enormous amount of cooling and that cooling may result in hydrate formation.

So, whenever we are operating such plans we have to see to it that the delta p that is a pressure difference across the valve is not too small or it is not too high. So, too small will be leading some pre cooling and if it is too high it may lead to the hydrate formation. So, these are the ways we have to optimally choose the operating conditions and the other equipment.

And external heating will be needed if there is any kind of hydrate formation of the formation of the ice.

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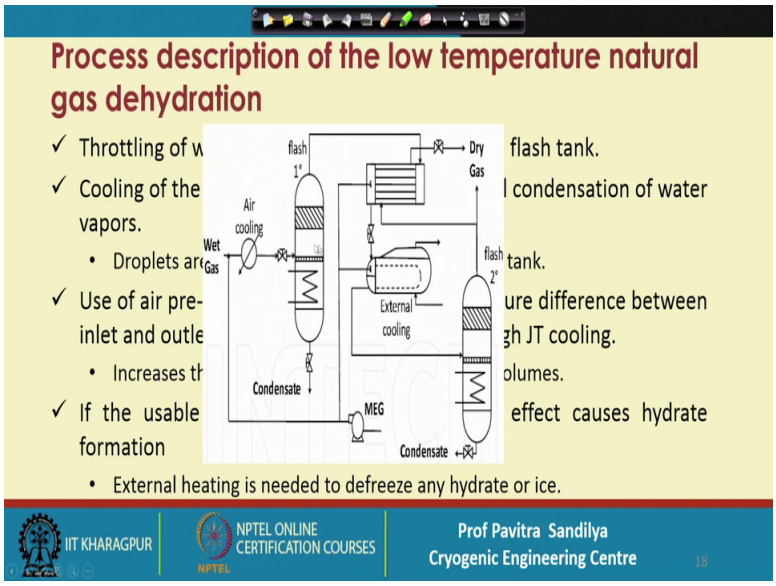

So, here is the representation of this whole process. Now wet gas comes and it is there is JT valve over here and this JT valve, then it causes the condensate will come out and then it is flashed over here, it goes again through a cooler and again it goes to another one and we here we find that we are putting a glycol as I we said that it works well with conjunction with another system like in this case, we are doing absorption.

So, this glycol is put to again dehydrate this thing and this thing is done in two steps to remove the condensate that is basically water from the natural gas and ultimately we get the dried gas from this second column.

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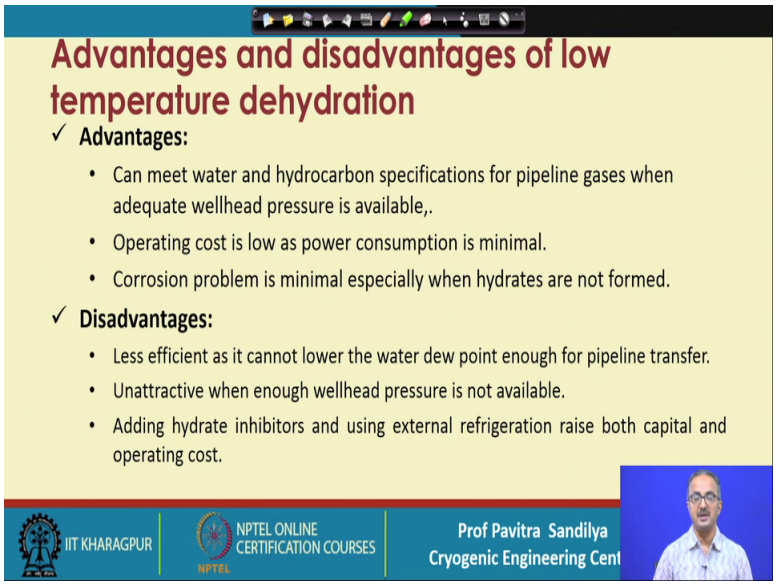

Now, the advantages and disadvantages are like this that. In the advantages, this low temperature dehydration can need water and hydrocarbon specifications for pipeline gases when we have enough or a high enough wellhead pressure available.

And their operating cost is low, if we have the naturally occurring pressure and the corrosion problem is also minimal especially when the hydrates are not formed, but their disadvantages are that they are less efficient as they cannot lower the dew point of the water for pipeline transfer and if they cannot lower the dew point, it means they will not be they are they are not removing enough water from the natural gas and their unattractive when we do not have enough wellhead pressure; that means, we try to utilize their wellhead pressure to derive this particular type of process without the use of any kind of compressors.

And we have to use some hydrate inhibitors and some external refrigeration and these will what will happen? They will be increase in the capital cost and the operating cost; that means, to remove water again we are adding another chemical which is in a way also increasing the processing cost of the natural gas, then we have the other methods like membranes permeation.

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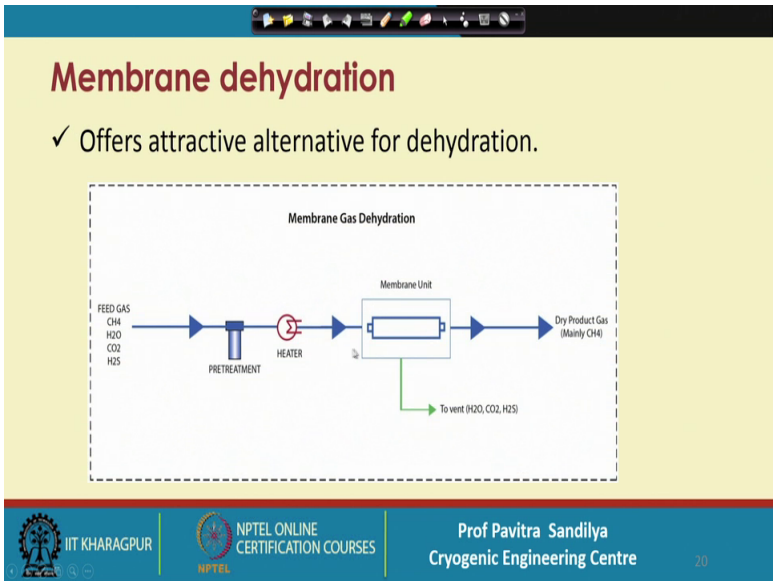

In the membrane permeation, what we are doing that we are having this feed gas which is pretreated to remove any kind of particulate matters, then it is heated and then it pass through some membrane.

And what are membranes? Membrane as we learnt; the membranes are some semi permeable barrier. So, they will retain some of this solute and some of them will be passing through the membrane. So, we find that the through the membrane these H2O, CO2, H2S, they are passing through; that means, the gas which is retained on the membrane will be almost a dry gas.

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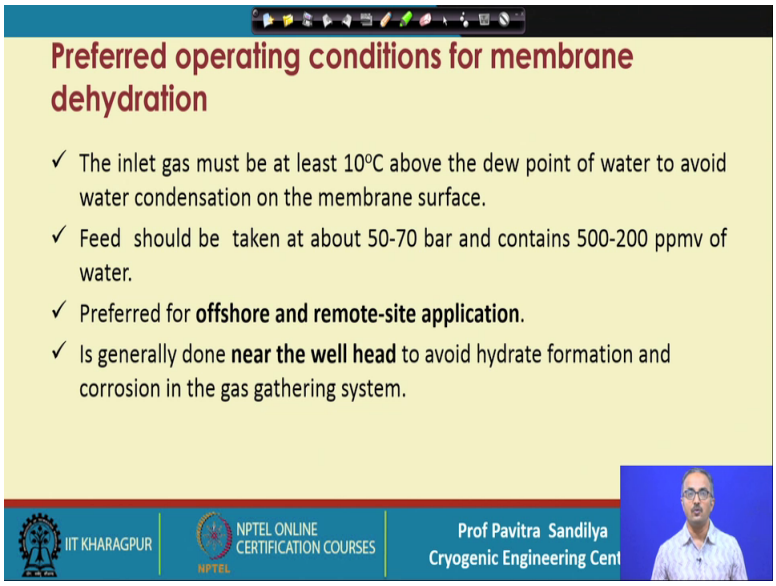

So, this is how the membrane is working for dehydration and the preferred operating conditions are like this that inlet gas must be at least 10 degree centigrade, above the dew point of water otherwise, what will happen? These water will get condensed and they will settle over the membrane surface and they will not allow further separation and the feed should be taken at a very high pressure with a very low contaminant because high pressure is needed for driving the particular solute through the membrane and these are generally preferred for offshored and for remote site applications.

And it is generally done near the wellhead because in the well head, there will be quite high pressure and also we can the temperature is high enough that it will avoid the formation of the hydrates and also corrosion in the gathering system. So, hydrate formation and the corrosion will be reduced in if we do it near the well head due to the high temperature.

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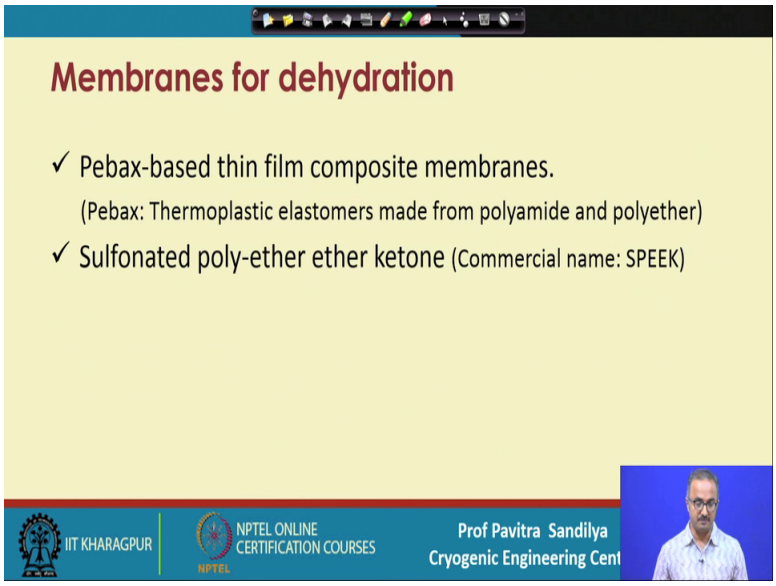

And these are some of the membranes used these are basically some hydrocarbon based materials, it feed backs which is basically a thermoplastic elastomer made from polyamide and polyether and we have another sulfonated poly-ether ether ketone and that is known more as SPEEK.

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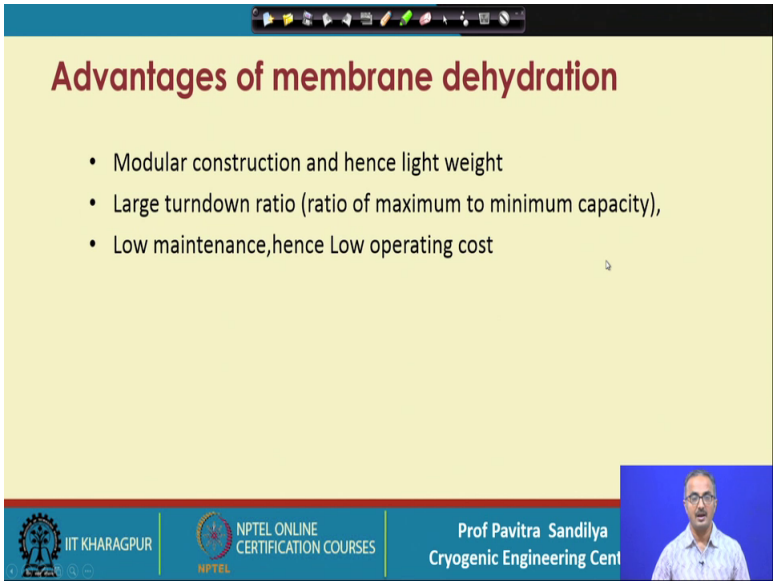

And here also advantages of the membranes that they have a modular construction; that means, under respect modular construction means they are coming in small small units and the advantage is this depending on the demand we can either reduce or increase the

number of a modules for operation. So, all the modules need not be run together. So, this is the advantage and then we have they are very large turndown ratio which means that the ratio between the maximum and a minimum capacity is quite large; that means, that they can handle large fluctuations of the feed flow.

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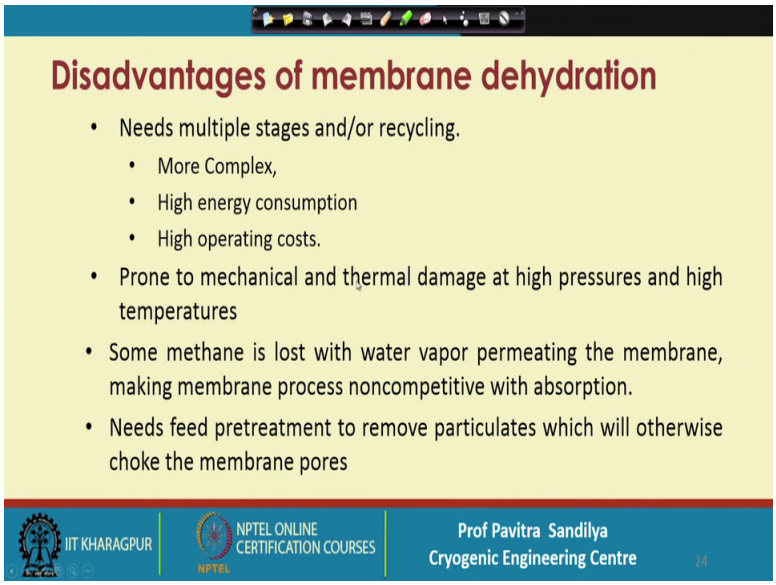

And they have a low maintenance and a low operating cost the disadvantages of the membrane pores are that they are quite complex, they consume high energy and they their operating costs are large because they need multiple stages and sometimes recycling and they are very prone to some mechanical and thermal damage due to a high pressure and a high temperature.

Some amount of methane is lost into the water vapor permeating through the membrane; that means, we are losing some of the methane which is present in the natural gas by permeation through the membrane which is not desirable and that makes a membrane non comparative with absorption because in case of a absorption no methane is dissolved in the solvent. So, that way membrane is not very good in comparison to the absorption process and these membranes need some feed pretreatment. Now otherwise what will happen any kind of particulate matters that are there in the natural gas will choke the membrane pores and it will reduce the efficiency of separation through the membrane modules.

Then lastly, we have the calcium chloride in this calcium chloride it is not much used.

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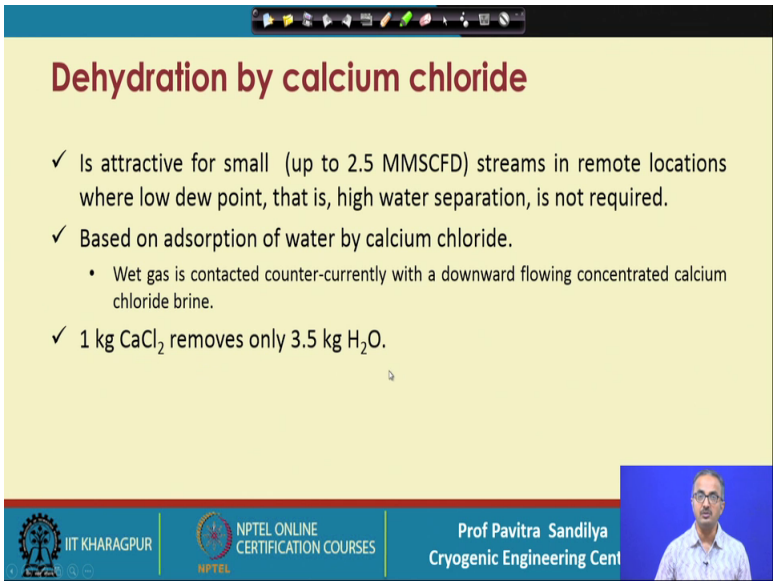

Now this is based on basically adsorption and what happens that it is for it is used for only small capacity about a 2.5 million standard cubic feet per day have we need very low dew point and ah, but it is not very good for high capacity even though it can give us a very good dehydration.

What we find that the wet gas is contacted counter currently with a downward flowing concentrated calcium chloride brine solution; that means, the wet gas moves up and the brain solution, which comes from the top to bottom and they get contacted counter currently and it is found that above one kg of calcium chloride is needed to remove about 3.5 kgs of H2O.

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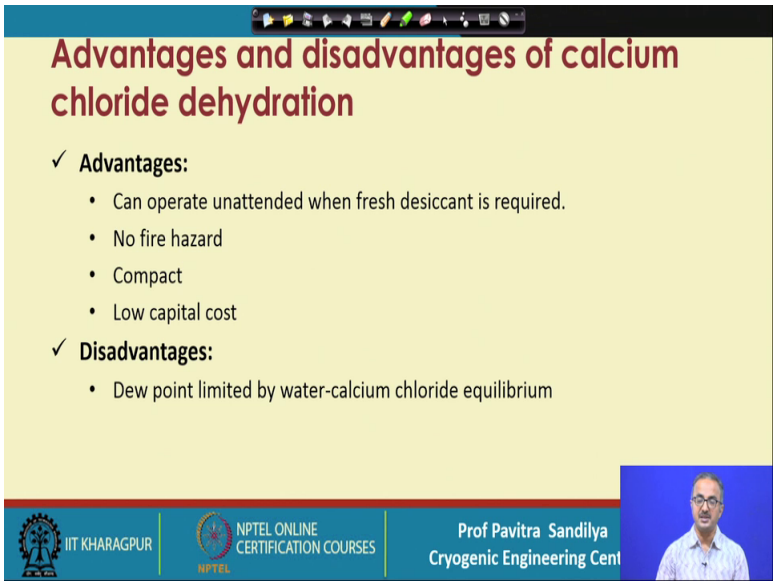

Its advantages are that it can operate on attended when we use a fresh calcium chloride it has no fire hazard, it is quit compact and it has a low capital cost on the other hand, the dew point limits the use of this water calcium chloride because all these things are the dictated by equilibrium. So, the dew point is one consideration which is there which can lead to this equilibrium um between the water and the calcium chloride and these are the various references to know detail about this processes.

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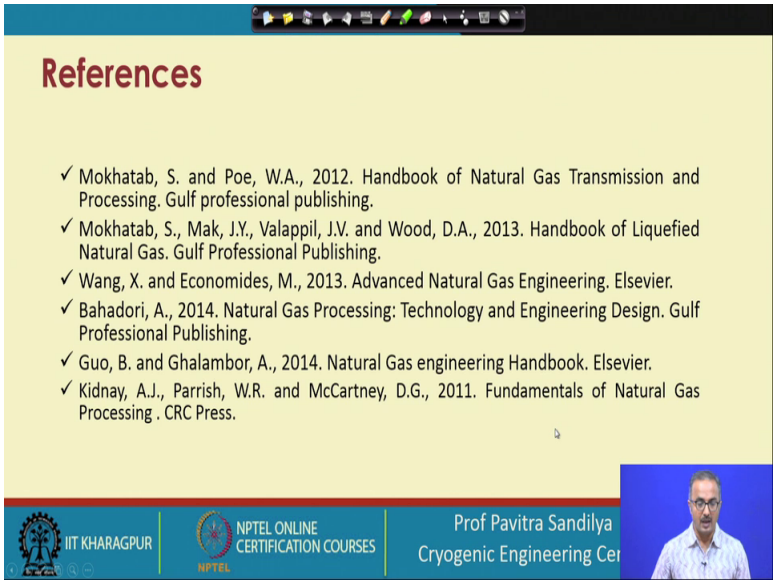

Thank you.