Upstream LNG Technology
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Lecture – 31
Separation by distillation

Welcome. Today, we shall look into another type of separation process that is used in the natural gas industries and that is by the distillation.

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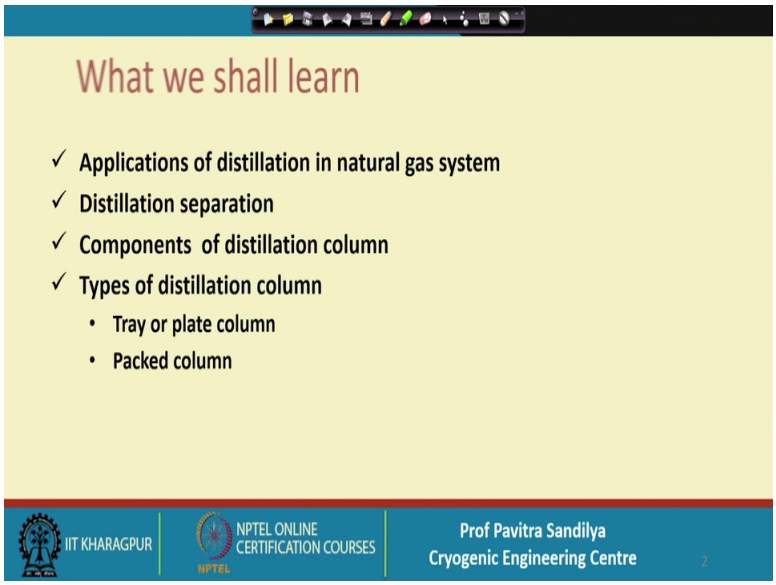

In this particular lecture we shall be learning about the applications of distillation in natural gas systems. The distillation separation operation some brief about them and the components of distillation column and the types of distillation column, these are some brief ideas which will be helping you to analyze the processes.

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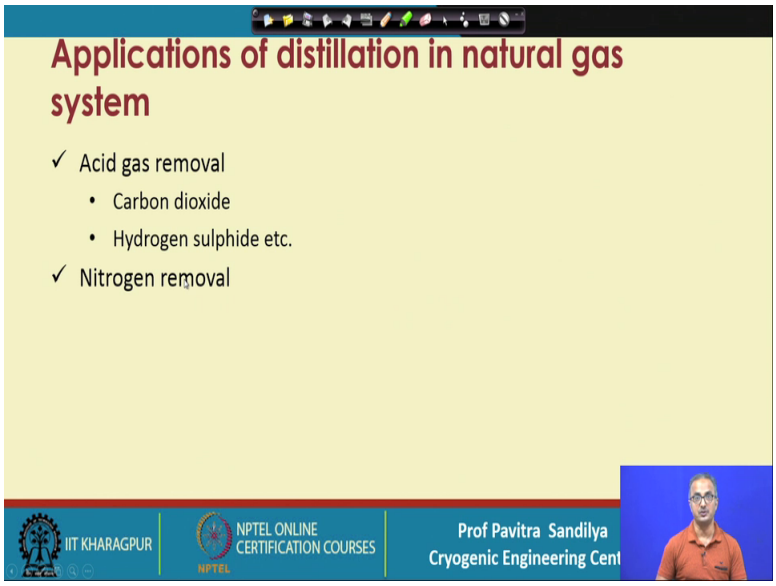

Now, coming to the applications of this distillation, in natural gas systems, we have basically go it for do for acid gas removal like carbon dioxide and hydrogen sulfide and nitrogen removal.

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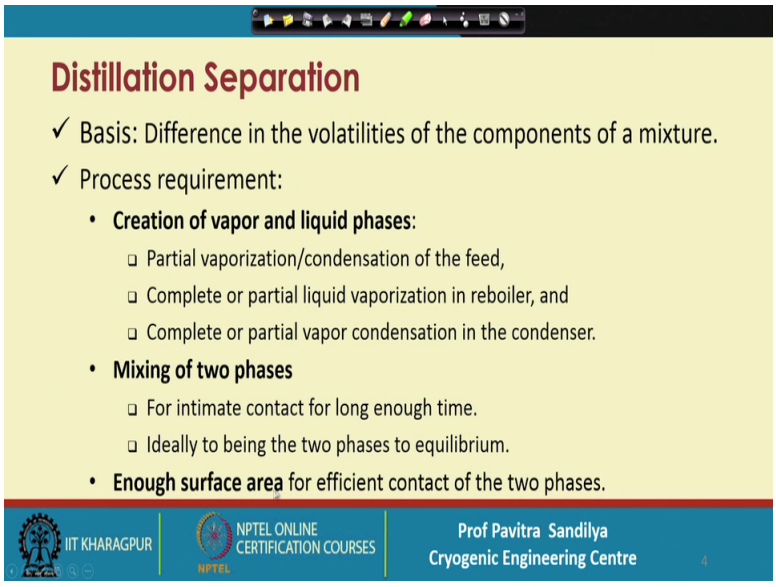

Now, distillation separation some basics about them that the basis of the separation is the difference in the volatilities of the components of a mixture about which we learnt earlier that we talk about the relative volatilities and those mixtures, which have relative volatilities quite away from unity or one can be separated by distillation and the process

requirement for distillation are some creation of vapor and liquid phases distillation can only be carried out when we have vapor and liquid phases, we cannot carry out distillation only with single phase.

So, to create these 2 phases, what we can do that we can either partially vaporize a liquid feed or partially condense a vapor feed or in the complete or partial liquid vaporization in the reboiler, we shall see what a reboiler is and similarly, we can have complete or partial vapor condensation in the condenser about this reboiler and condenser we shall be learning a bit later.

Then we have the mixing of two phases; that means, after creating the 2 phases, we have to ensure that the 2 phases come to very intimate contact for long enough time. So, that all of the components whether the higher volatile components can give have a chance to go to the vapor phase, but preferentially and the lower boiling point higher boiling point components can have time to come to the liquid phase preferentially. So, with these phases have to be contacted intimately for a long enough time to affect the separation and is a largely, we should have enough surface area this surface area is needed so that the two phases can come to intimate contact with each other.

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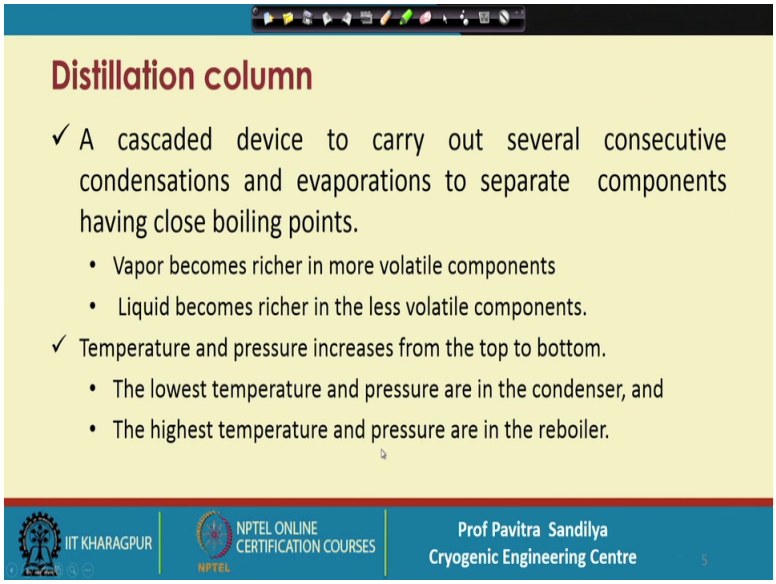

Now, what is a distillation column in distillation column we carry out distillation and this is a cascaded device to carry out several condensations and evaporations subsequent on different plates or trays, here we see that the separation of these components of having

close boiling points can be done in this column. Understand this if the boiling points are quite different, then we do not need distillation simple condensation or vaporization can affect the separation. So, in case of distillation, we need that the boiling point should be close enough and, but not too close so that the relative volatility do not approach unity.

Now, what we find that doing this contacting the vapor becomes richer in the more volatile components while the liquid becomes richer in the this volatile component the temperature and pressure keeps changing in the column from the top to bottom, we find both the temperature and the pressure increase temperature is lowest at the condenser and so, is the pressure similarly the temperature is highest and also the pressure is also highest at the reboiler the pressure is lower at lower at the top because as the vapor passes flows upward what it finds that it finds some pressure drop along the column height.

So, the pressure starts decreasing from the bottom to top and at the top we are condensing; that means, we are putting the lowest temperature in the column to condense, the outgoing vapor from the column and at the bottom, we are providing heat to vaporize the outgoing liquid from the column. So, that is why we find there is a gradient in the temperature as well as in the pressure.

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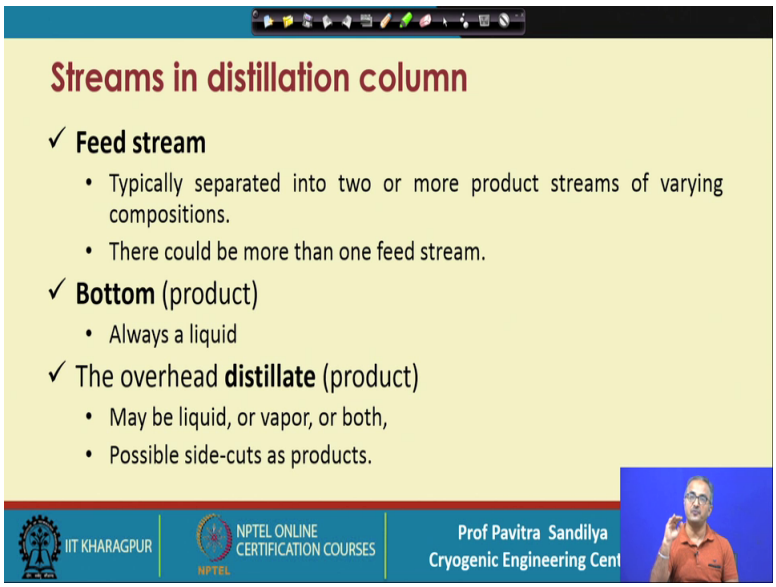

Now, the basic streams which are needed in the typical distillation column are a feed stream the feed stream will be having 2 or more than 2 components and which will be

again separated into 2 or more product streams, then there could be more than one feed stream in a column, we have some bottom product in this bottom product, it will always be general liquid and this will be containing the heavier components in a mixture, then we have the overhead distillate product and this will be having the lighter components..

And this may be obtained as a liquid a vapor or both as liquid and vapor there could be many possible cut side cuts; that means, from various points locations on a column we can have several other products this is especially true for the refineries.

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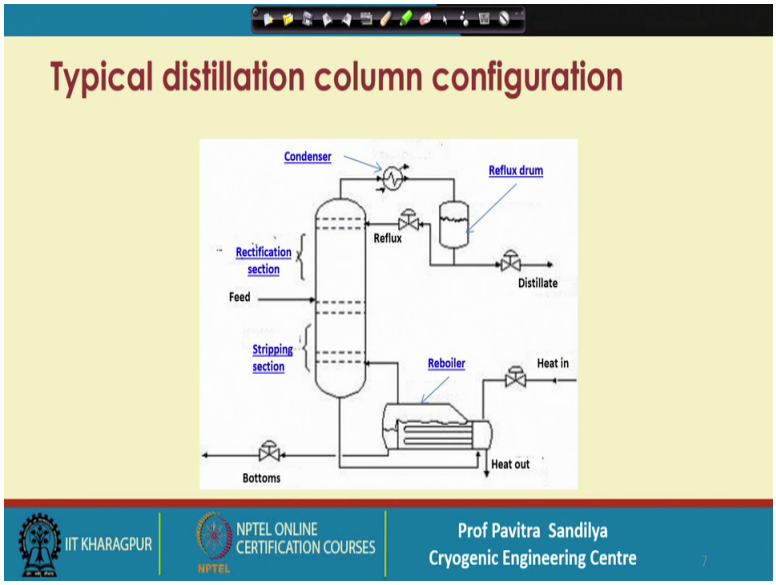

Now, here is a typical configuration of distillation column, first, we find that this column has one feed coming inside and then according to the feed location we are dividing the column into two sections, first is the rectifying section.

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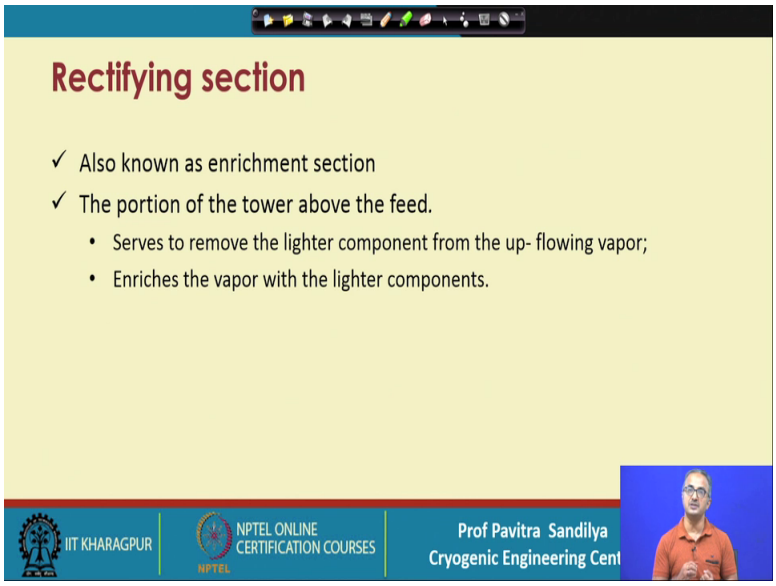

This rectifying section is also known as enrichment section and this is the portion above the feed and it serves to remove the lighter component from the up flowing vapor; that means, what will happen the lighter components from the liquid phase will go more to the vapor phase. So, that is how we are enriching the vapor with the lighter component and then we have the stripping section which is below the feed stage.

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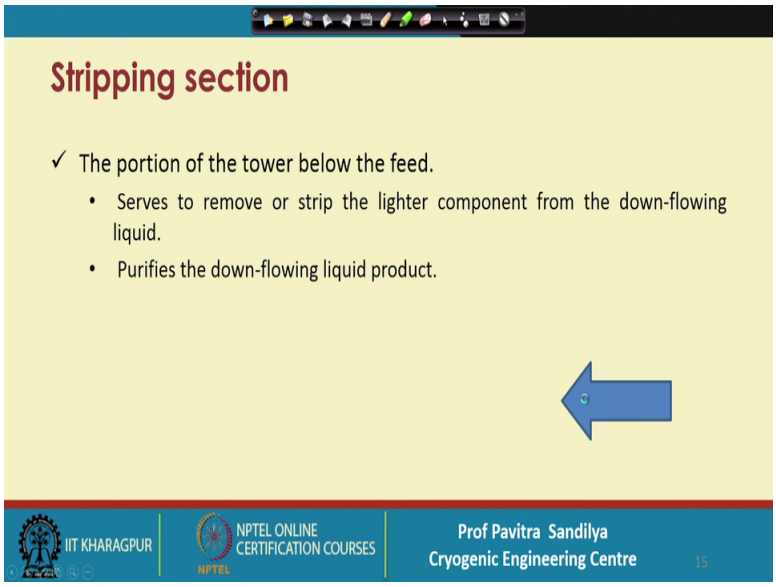

And it serves to remove the lighter component from the down flowing liquid; that means, the lighter components the liquid is coming down the whatever lighter components or

high boil low boiling point components are there, they will be going more from the liquid phase to the vapor phase, thereby making the liquid richer in the high boiling point components.

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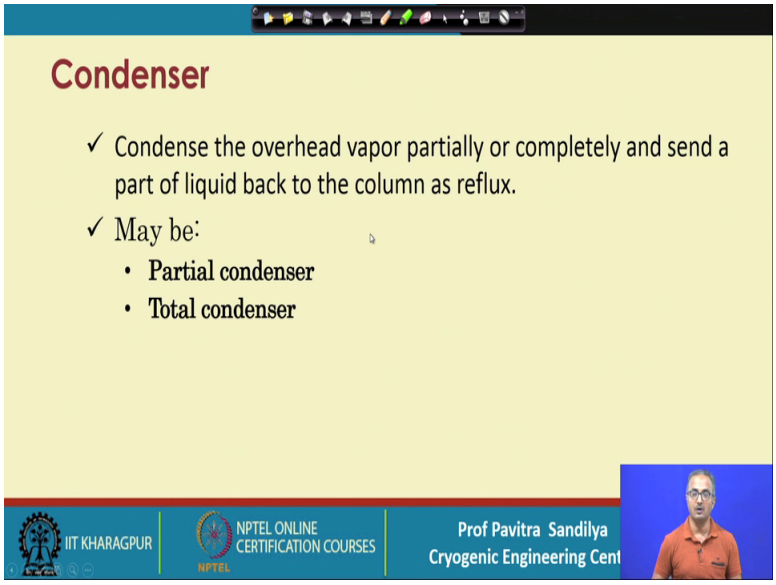

Next we have this top vapor is taken to a condenser and what are the condenser do this condenser each condenser condenses the overhead vapor partially or completely and it sense a something a liquid called reflux. So, this is the condenser and the condenser may be a partial condenser or may be a total condenser.

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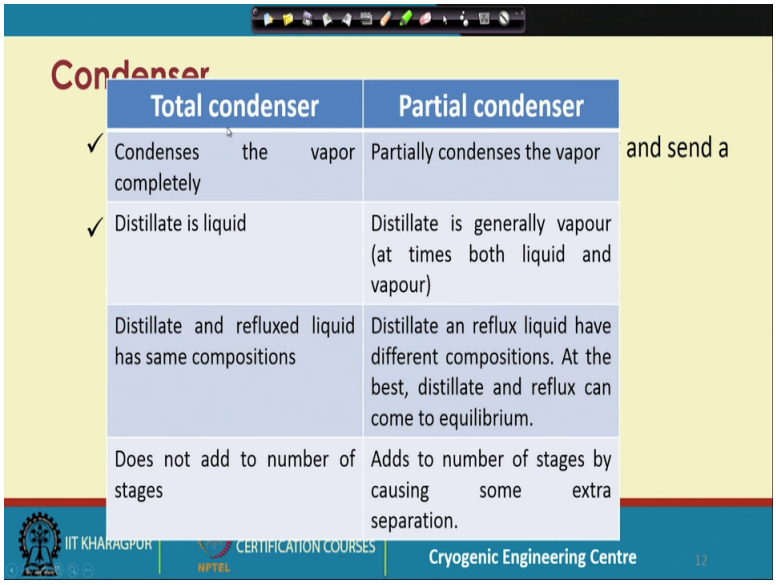

Total condenser	Partial condenser
Condenses the vapor completely	Partially condenses the vapor
Distillate is liquid	Distillate is generally vapour (at times both liquid and vapour)
Distillate and refluxed liquid has same compositions	Distillate an reflux liquid have different compositions. At the best, distillate and reflux can come to equilibrium.
Does not add to number of stages	Adds to number of stages by causing some extra separation.

And let us now look into the difference between this partial condenser and total condenser total condenser means the vapor coming out from the column is completely condensed whereas, in case of partial condenser, the vapor is partially condensed the distillate in the total condenser is a liquid, whereas, in case of partial condenser, it may be vapor or it may be a mixture of liquid and vapor this vapor and liquid mixture its means that I can have both the liquid and the vapor as the product stream separately.

Then the total condenser the distillate and a reflux liquid have the same compositions whereas, in case of partial condenser the liquid and vapor have different comp compositions and at the best this liquid and vapor from the partial condenser can come to an equilibrium.

That means, a partial condenser can affect some more separation in addition to the separation that is obtained in the actual column then the total condenser does not really add to any number of stages, but whereas, the partial condenser because it can affect some more separation. So, it may act as an additional stage about which we shall be learning later.

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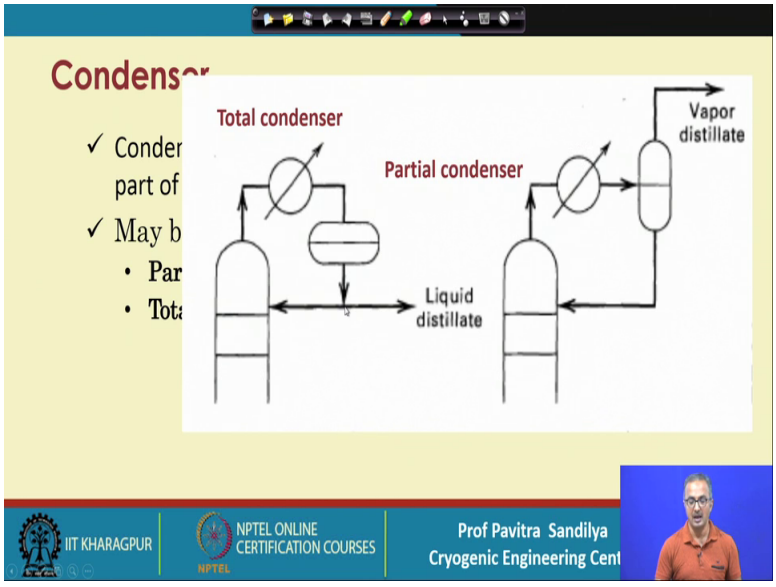

Now, here are the configurations of the total condenser, what we find here that the vapor is coming here in the condenser and it is completely the condensed to liquid and we are getting the distillate as the liquid, whereas, in partial condenser the vapor goes into the condenser and here we find that both liquid and vapor are getting separated and this is a

phase separator from which we are getting the vapor distillate and the liquid portion is refluxed back to the column.

Now, we see that there is a reflux drum which is carrying the condensed liquid from the condenser.

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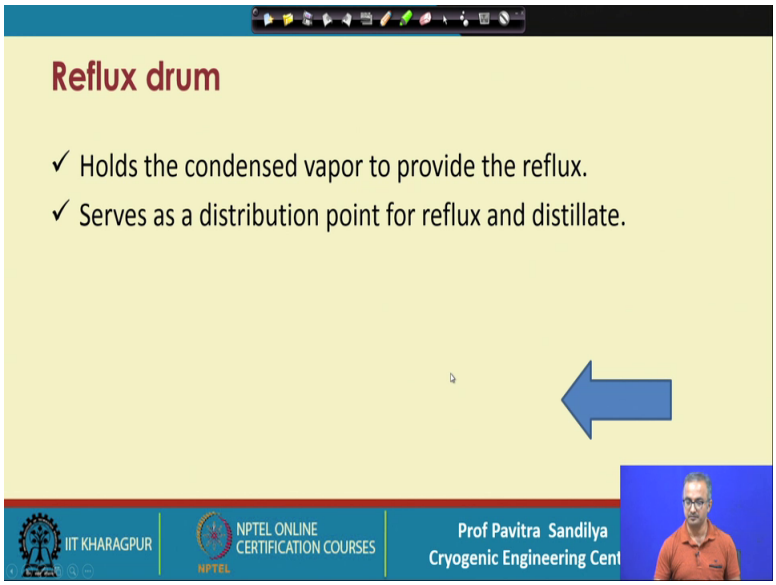

And what is job is it holds the condensed vapor to provide the reflux and serves as a distribution point; that means, we are keeping the condensed vapor in the reflux drum and we are adjusting the amount of reflux to be given to the column and so, the distillate amount will also will be changing.

Now, at the bottom the bottom liquid comes down and then it goes to a reboiler, the reboiler is operated by adding some external heat as the condenser is also operated by taking out the heat by some kind of cooling medium. So, in this reboiler what we have.

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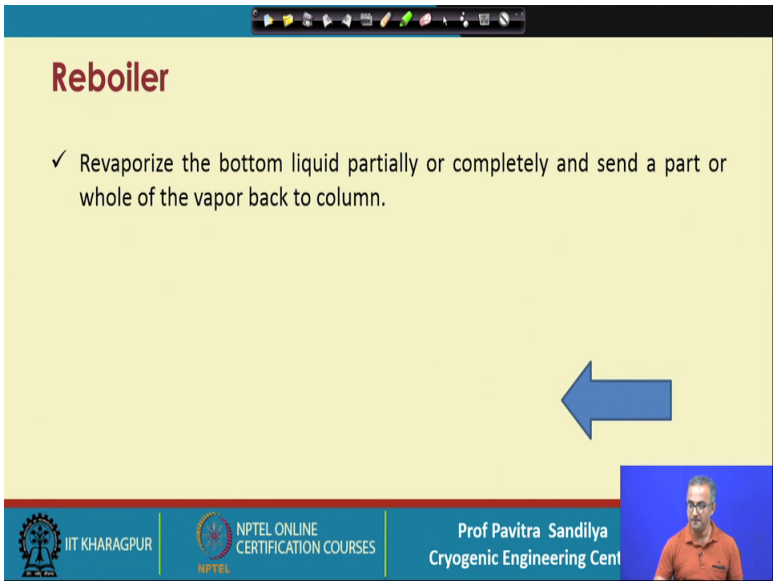

The reboiler; what it does that it revaporizes the bottom liquid either partially or completely and send a part of the whole vapor to the column and then what we find that from the reboiler, we are getting the bottom product. So, this is a typical configuration of a distillation column variations may be found as per the different types of separations by distillation in different applications.

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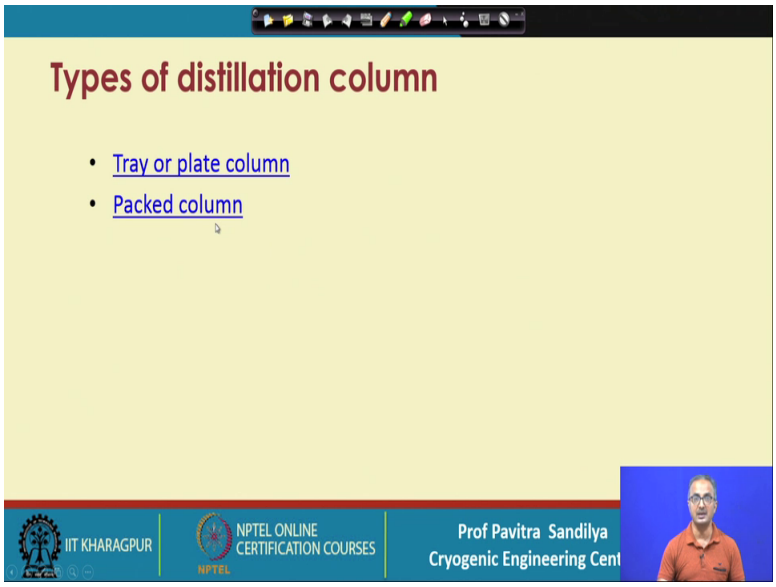

Now, there are various types of a distillation column. Broadly, they are divided into 2 types. One is the tray column, another is the packed column and that now let us see what is the tray column or plate column.

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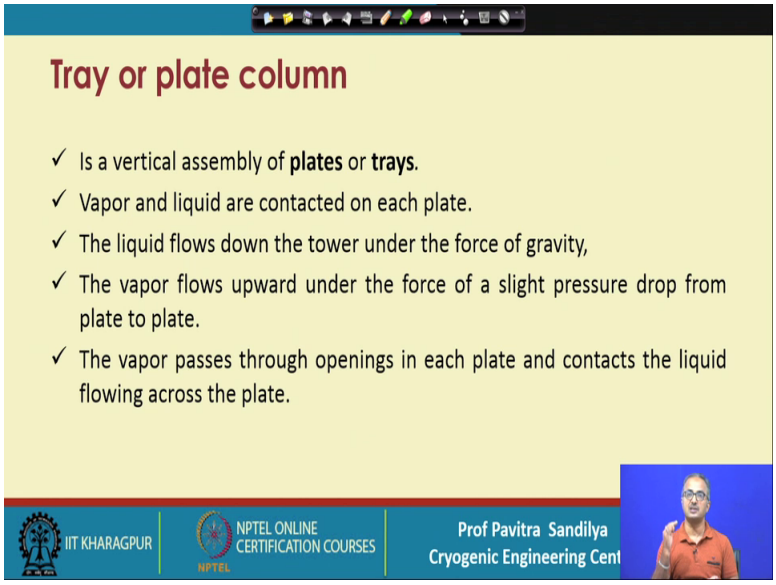

These tray columns are having some assembly of trays or plates and the what happens that the vapor and liquid the vapor is moving going from the bottom to top where liquid is coming to the top to bottom, they are contacted on each of each plate the contact on each plate and what we find that during their contact in this column, these they get intimately mixed and the liquid flows down the tower under the force of gravity whereas, the vapor moves up the column due to slight pressure drop from bottom to top.

So, across the plate there will be some pressure drop and due to this pressure drop the vapor will be able to move upward and the vapor passes through the some openings in the plate, we shall cease the constructional plates, we will find there some openings in the plate through which the vapor comes out and the liquid the design is such that we do not want the liquid to come out through the pores this holes in the plates, they will be coming through some other means about which we shall see later on.

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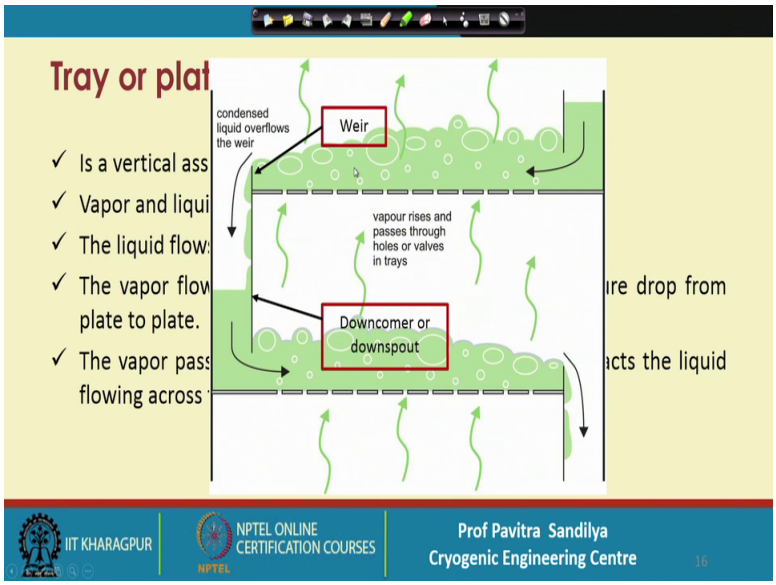

So, here we have the typical figure of a plate column, here we find there are this is a plate these 2 are plates and these plates have these holes through which the vapor moves out and what we find that at the end one? End of the plate we have the weir this weir helps in retaining some of the liquid on the plate and without the weir what will happens we will not be able to retain the liquid and if you do not have enough liquid on the plate there will not be proper mixing between the vapor and the liquid.

So, this weir is put here and this height of the weir has to be also adjusted. So, that we have just enough amount of liquid because if you put too much of height of the weir we will find that it will be difficult for the liquid to come out of the particular plate. So, this weir is provided to retain some of the liquid and then what happens the liquid comes out through this particular channel what we call the down comer or downspout.

So, through this particular downspout the liquid comes out and arrives at the lower plate and what happens meanwhile that the vapor goes through the holes and then get mixed in the with the liquid here there these bubbles are showing that the vapor bubbles are getting mixed with the liquid and after enough mixing. These vapors are traveling out and they are travelling out of this particular liquid and this, they are then moving to the upper plate and that is how this whole column operates there are many design issues which about which I am not talking about, but this is the overall configuration of a tray column.

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Now, we have again various types of trays for example, we have a sieve tray.

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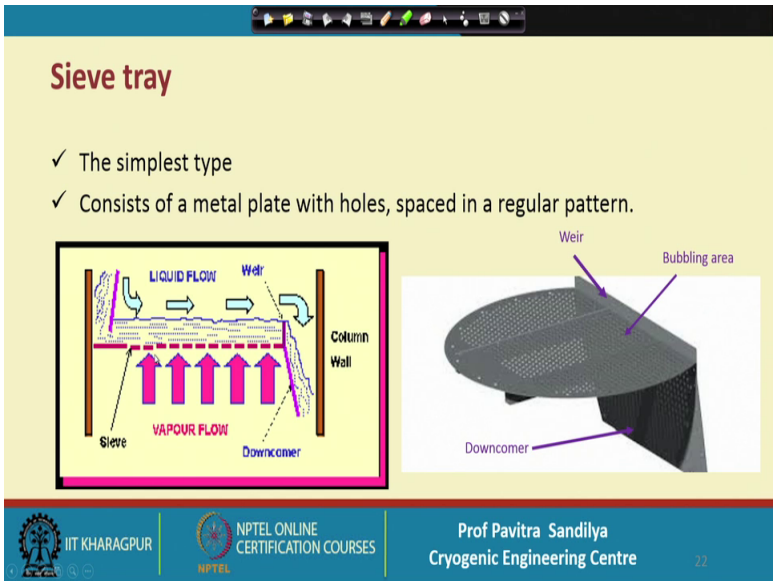

These sieve tray is very simplest of the trays and what it consists of that simply, we have a tray with which some sieves or holes and through these holes the vapor is coming out and the liquid is passing over this plate, let me mention that these liquid is not coming out through the holes because we are putting enough pressure of the vapor to prevent the liquid from coming out through the holes; that means, if there is any kind of decrease in

the vapor flow rate, we may find that the liquid may come out of this holes and that is the situation we want to avoid.

Now here is a real life sieve tray with a weird over here and this is the down comer downspout and here we can see that these are the holes on the sieve plate. Next we come to the bubble cap tray which has been designed.

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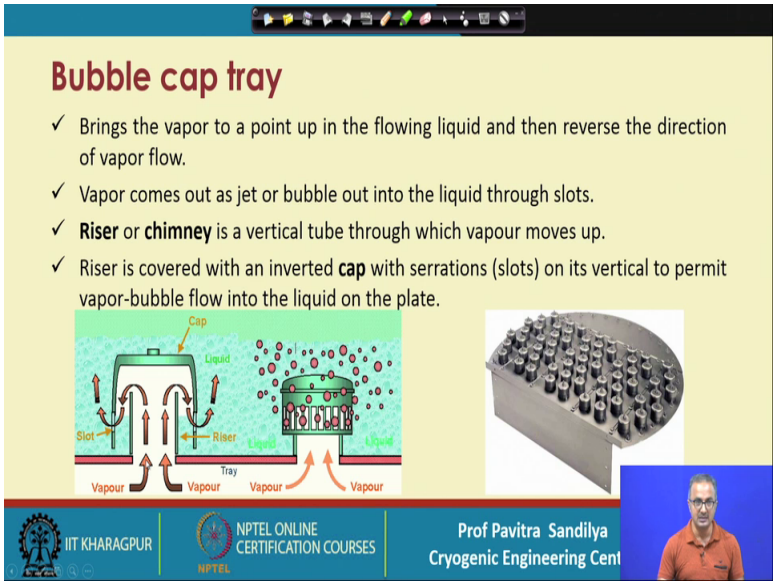

So, that we can take care of some of the difficulties with the plate this sieve trays because sieve tray has this difficulty of having we cannot have too low a liquid otherwise what will too low a vapor flow rate otherwise what will happen the liquid will come out through the holes.

So, for that bubble tray was proposed and in this particular tray we find that the design has been modified again we have some hole to vapor to come out, but now the holes are covered with what we call the riser or the chimney now what happens these vapors are coming out from the holes and then they take a turn here and then these chimneys are covered with a what we call cap. Now in these caps, we find that this caps up some serrations or some these serrations with some kind of openings in a cap.

So, these vapors are coming out and they are coming out through these serrations and bubbling through the liquid. So, in this manner, what we are finding we are able to

prevent the liquid to come out through the holes even when the vapor flow rate comes down. So, here is the photograph of an actual bubble cap tray.

Now, this particular tray works quite well only thing is this cap movement up and down will be decided by the flow vapor flow rate. Now you can see that to make them, this cap move up we need enough inertial force for the vapor to push it up. So, this gives some kind of a pressure drop to the vapor.

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Now, these are the various kinds of designs of the bubble caps the last kind of tray which is still an improvement over the bubble cap tray is a valve tray.

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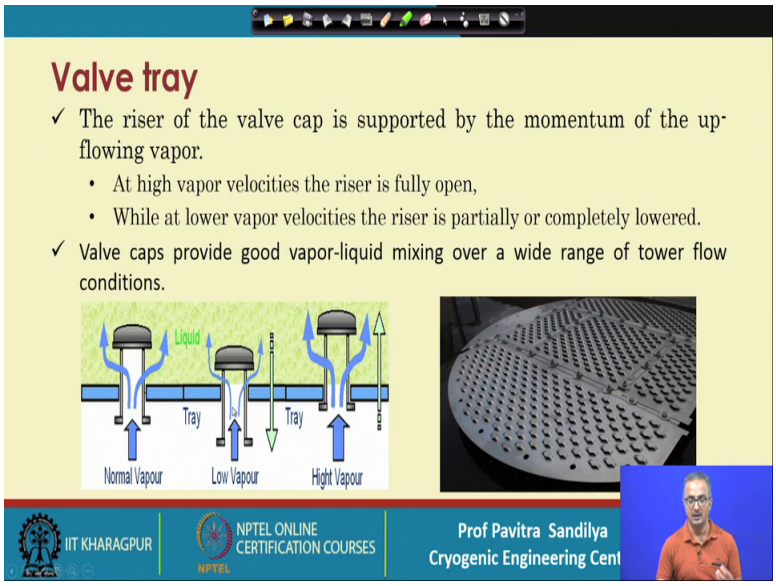

The improvement comes in the way of reducing the pressure drop across the valve. So, what we find that the valve cap is again similar to that, but there is a simpler construction this, this is the valve and what happens this valve just moves up and down this thing along with this particular riser.

So, this whenever the vapor flow is not there this valve this will sit down on the tray and whenever some vapor float is there it will push the valve up and the vapor will flow out and the vapor will not be taking any kind of turns to this valve. So, that way we are finding that we are able to reduce the pressure drop across the plate and here we find that depending on the vapor flow rate, the valve will either move up or come down and this is the figure of an actual valve tray.

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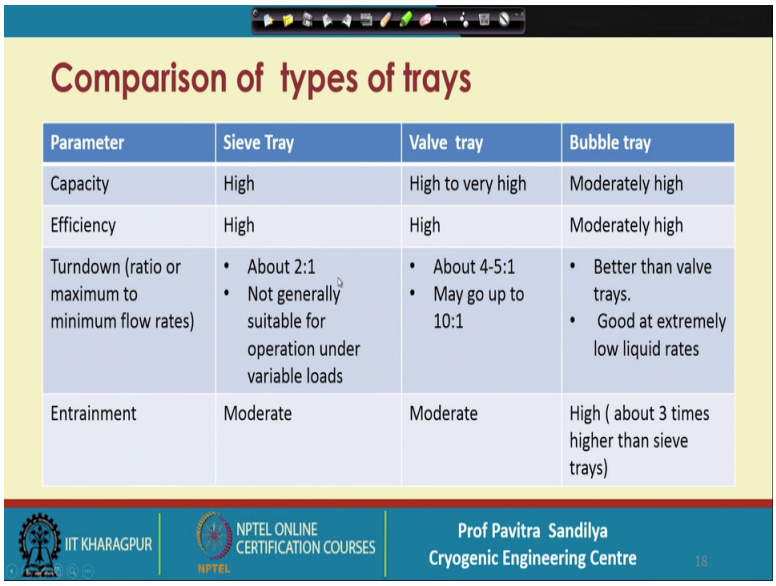

After this tray columns and we find that these are the various ways of comparisons because these three types of trays are available. So, these have been compared based on the capacity efficiency turn down ratio that is the ratio of the highest to lowest flow rate the entrainment. Entrainment means that we warned that when the vapor is moving out of the liquid, it should not carry along with it in the liquid otherwise we will be losing the liquid also; we shall be losing the separation efficiency.

So, this entrainment means the entrainment of the liquid by the vapor and we want to reduce it. So, on that respect also we differentiate these various types of trays.

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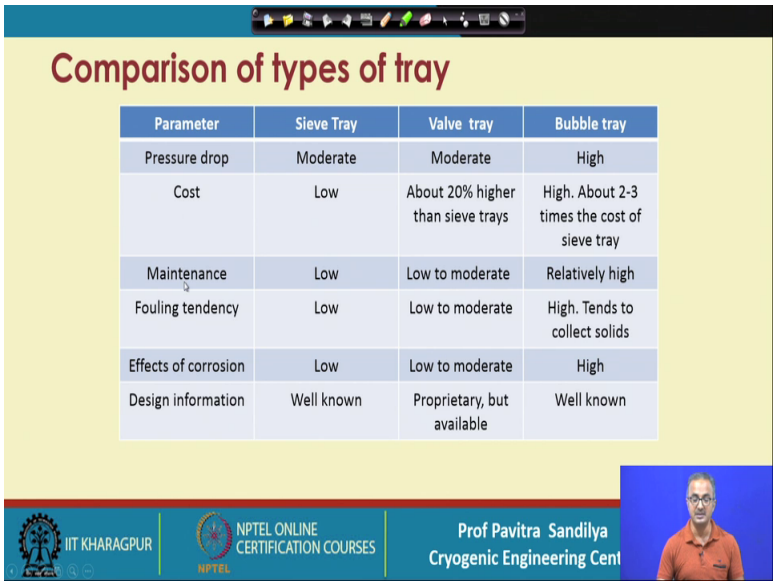

And then we have the pressure drop that is very important because it decides the pumping power, then the cost the maintenance how much maintenance is required for all of them the ease of maintenance the fouling tendency, the effects of the corrosion and design other information.

So, we find that based on these various parameters we can differentiate between these various kinds of trays, these are also given in more detail in some literature on this distillation column. So, I am not going into in the detail right now as and when required we shall be talking more about these topics.

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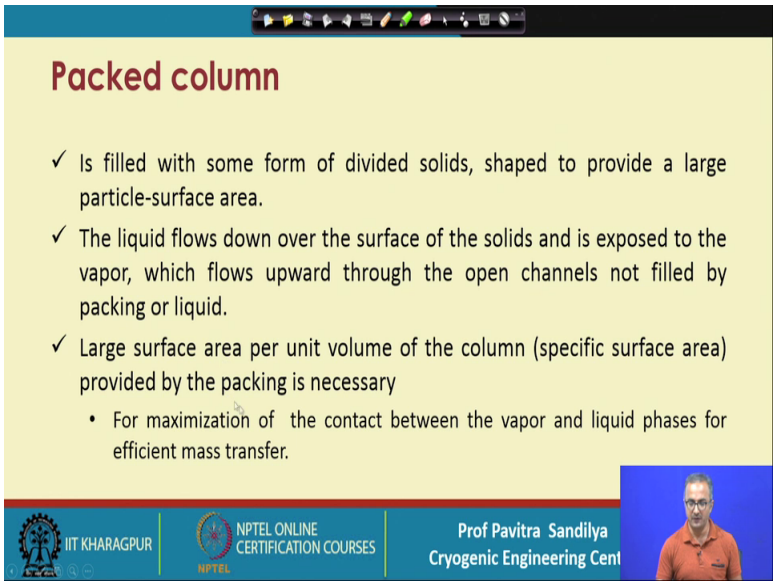

After this we come to the packed column. So, in the packed column, what we have? We have some solids divided solids which are just packed inside the column, this solids can be of different sides can be made from different types of materials and their basic purpose is to provide the surface area the packing the liquid will be flowing over the surface of this packing and the vapor will pass over across it. So, that on this packing surface there will be the contact between the liquid and the vapor. So, we have to design the packing in such a manner that we can maximize the area for contact that is why we will find that there are different types of packings.

The so, what happens that the liquid flows down and during this they have the contact between the vapor and for we want to have large surface area per unit volume of the column; what we call the specific surface area for maximizing the mass transfer for efficient mass transfer and separation.

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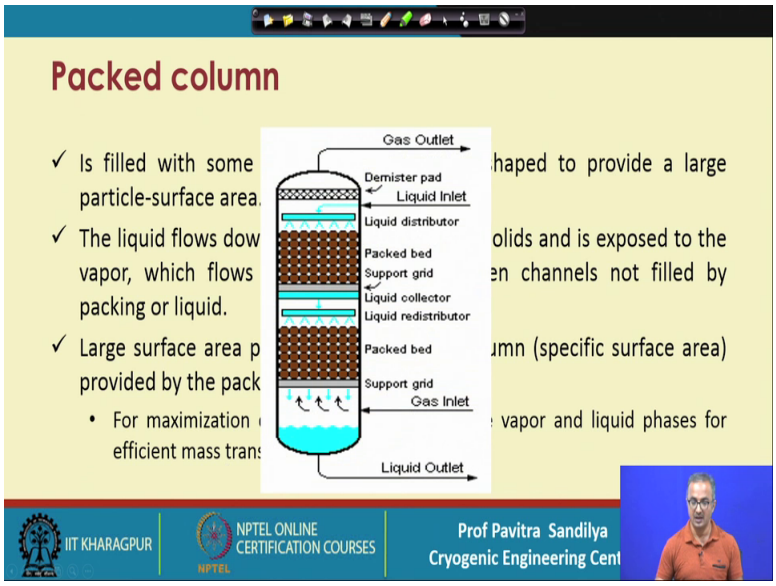

So, here we find a typical packed column, here we find that we have the packings at both the rectifying section and the stripping section and here we have some support grid to support the packing. So, to make them stay in place and then we have some liquid distributor.

So, that the liquid which is coming; coming can be distributed across the cross section of the column and then we have some demister pad this demister pad is serving the purpose of reducing the entrainment that is if there is any kind of liquid carryover by the vapor those liquid are tapped and they are sent back to the column. So, we have all this, but the these kind of things in the particular packed column.

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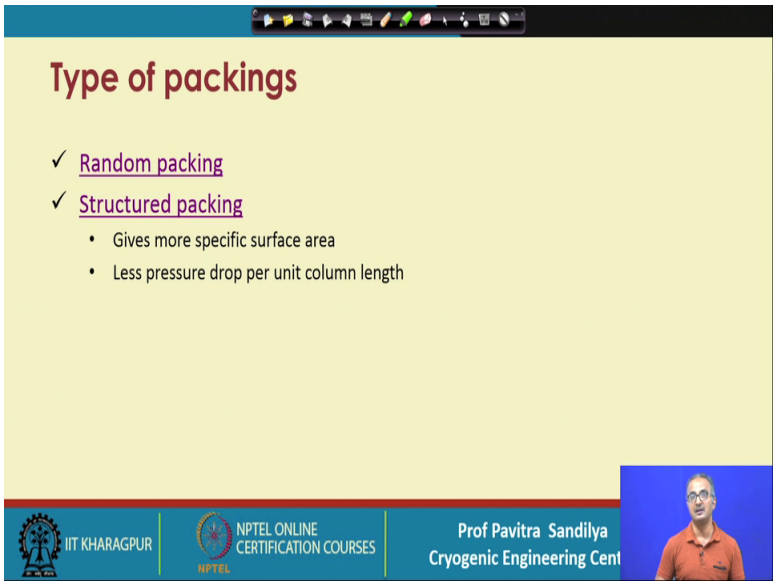

Now, we see the various types of packings available one is the random packing another is the structured packing.

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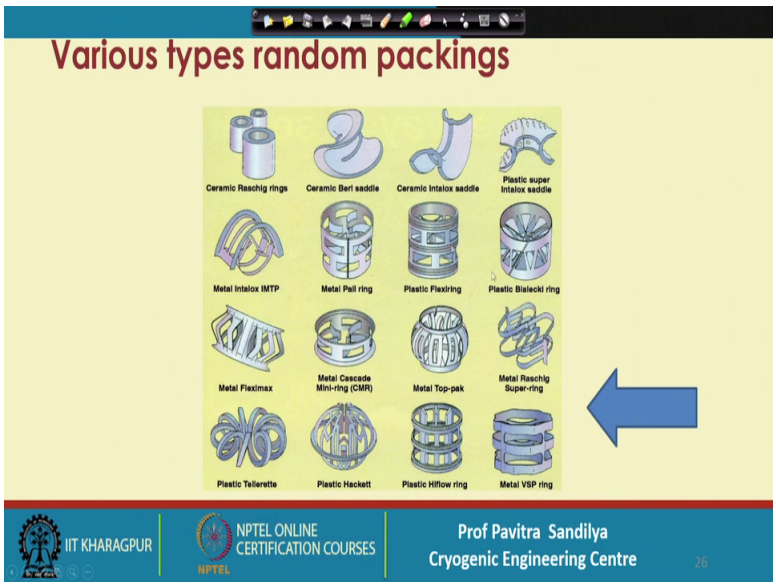

So, let us see what a random packings are here we find that they randomly the name comes because these kind of packings are come coming in small small pieces and this is a randomly put in the packing in the in the packed bed. So, we have different types of random packings like Russia, Green Burl, Saddle Interlock saddle and so on and so forth.

So, all these packings are have been proposed by different researchers by different industries and some of them are also proprietary in nature. So, all these packings; they are differentiated in terms of the surface area they offer and also in terms of the pressure drop because pressure drop is a very important consideration in designing of any of these columns.

So, all these packings will be providing us different surface areas as well as they will be giving us different types of pressure drop. So, depending on the particular case, we have to choose a particular type of packing and there can, could be many more packing other than the ones which are shown here. So, after these random packings, we have structured packing.

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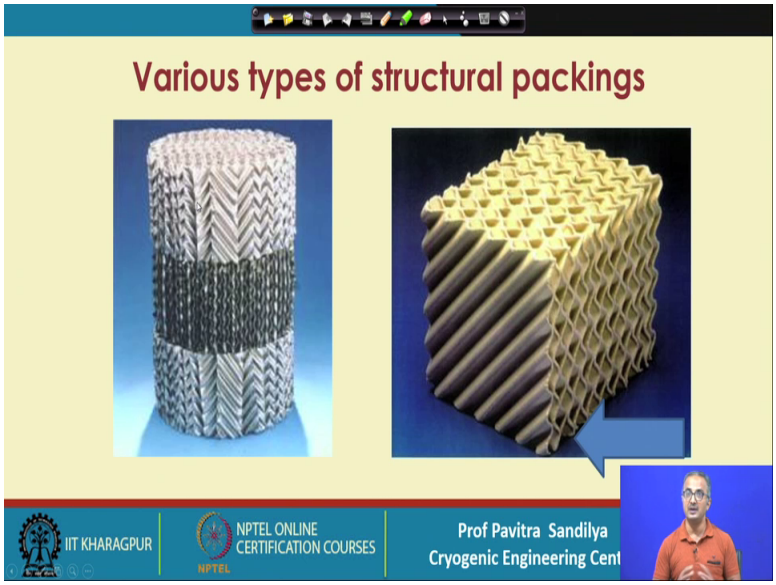

And in this case we see that these packings are struck called structured because there is a particular pattern in which they have been made and as you can see from these that there are the flow path is very well structured which is unlike the case of random packings; in random packings the flow path is the flow trajectory is not well defined it can be random, but in this case we can see that the flow path is well defined that the flow will happen only through these points.

So, this is how these this flow takes place and when the flow path is well defined what happens in this that we are getting lower pressure drop. So, other than the lower pressure drop this kind of structured packing also offers a better contact between the two phases.

So, after the structured packing these as I said that these are giving more specific surface area as well as lower pressure drop in that way, we find that structured packings have better efficiency than the random packings; however, because of their construction they are more expensive than the random packings.

So, both these packings are available and used commercially, but depending on the particular situation, we have to choose one or the other nowadays the industries are slowly migrating towards the structured packing.

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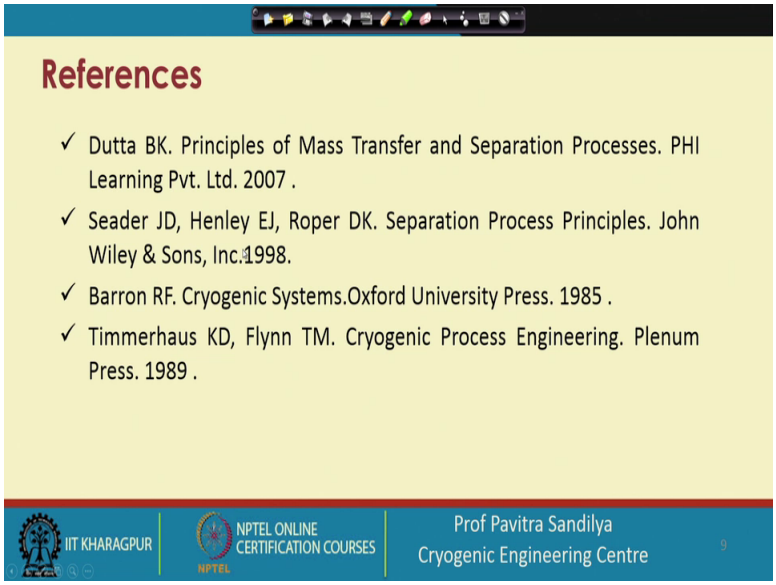

Now, these are the various references in which you can find the details about all these types of the topics covered in this.

Thank you.