Process Equipment Design
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Lecture –29
Design of Reboiler-3

Hello everyone. This is 29th lecture of the course Process Equipment Design and I welcome you all in this lecture and here we are going to discuss design of reboilers. If you remember the previous lectures, we have started design of reboiler from 27th lecture and there we have classified the reboilers. In the previous lecture that is in 28th lecture, we have started design of kettle reboiler and in this lecture we are continuing the design of kettle reboiler.

So, in the last lecture as far as kettle reboiler design is concerned we have found out the overall heat transfer coefficient and observe that it should be within the limit and we also have computed bundle diameter as well as shell diameter.

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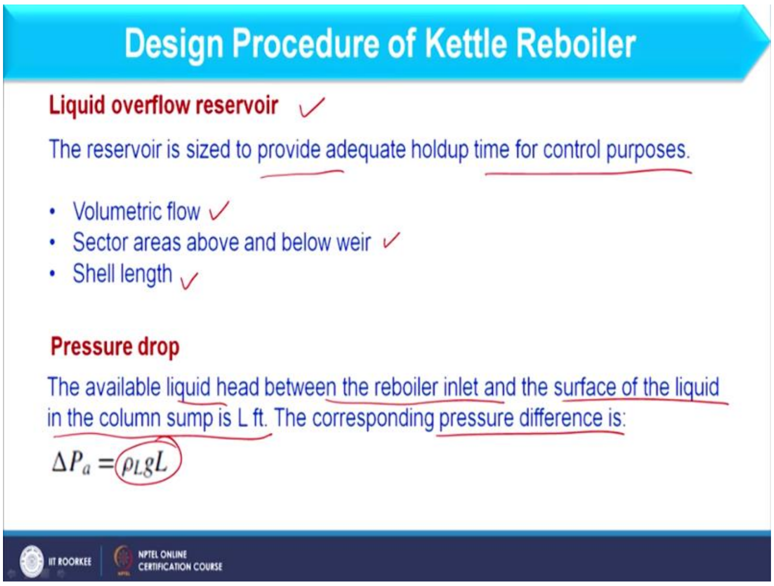

And now we will focus on the pressure drop part of the reboiler to ensure that liquid should come automatically from distillation column bottom to the reboiler. So, further design procedure of kettle reboiler says that we have to design liquid overflow reservoir. So, reservoir is sized to provide adequate holdup time for control purpose. And as far as liquid overflow reservoir is concerned we have to find out following parameters such as volumetric flow, sector area above and below weir.

And we also have to find out shell length because tube length is different and shell length is different. So, how we should find out shell length that is another part of liquid overflow reservoir. And once you have liquid overflow reservoir design we should proceed for pressure drop calculation. So, in this pressure drop in kettle reboiler the available liquid head between reservoir inlet and the surface of the liquid in the column sump is L.

So, the corresponding pressure difference we can find out as rho L g L. So, what is this is L? This L is from the reboiler inlet to the liquid available in distillation column. So, this pressure drop is in the distillation column side not the reboiler side. So, we consider this pressure drop as available pressure drop.

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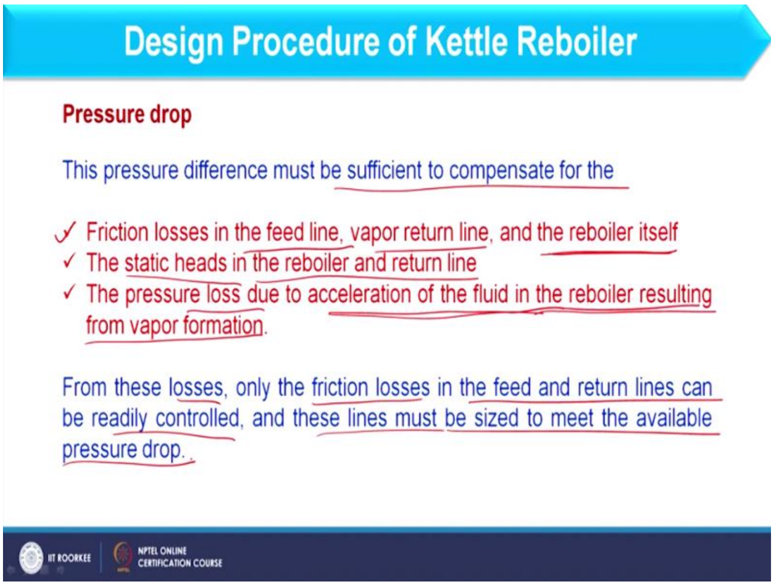

And further the pressure difference must be sufficient to compensate the followings. So, if you have the available pressure drop that pressure drop should be sufficient to consider the compensation corresponding to pressure drop in reservoir. So, the pressure drop we have obtained in column side that should be sufficiently high than the pressure drop, available in reboiler side.

And it can be divided in different section such as friction loss in feed pipe, vapour return line and the reboiler itself and secondly static heads in reboiler as well as return line and thirdly pressure loss due to acceleration of the fluid in a reboiler resulting from vapour formation. So, as far as pressure drop in reboiler side is concerned we consider that in the reboiler section either it is feed line or reboiler itself or the return line fluid will be available in that continuously and therefore we should consider static head in these sections.

Apart from this because fluid is continuously moving in the reboiler return pipe and feed pipe so friction loss should be there. And we also have to consider the pressure loss which will be obtained by vapour formation when vapour is moving in a reboiler, so it will give certain acceleration. So, all these three factors we should consider to find out pressure drop in kettle reboiler.

And this pressure drop combinedly should be less than the pressure drop available which we have discussed in the last slide. So, from these losses only the friction losses in the feed and return lines can be readily controlled and these lines must be size to me the available pressure drop. So, in this way we have to consider pressure drop in different parts of kettle reboiler. First of all, we will focus on static head.

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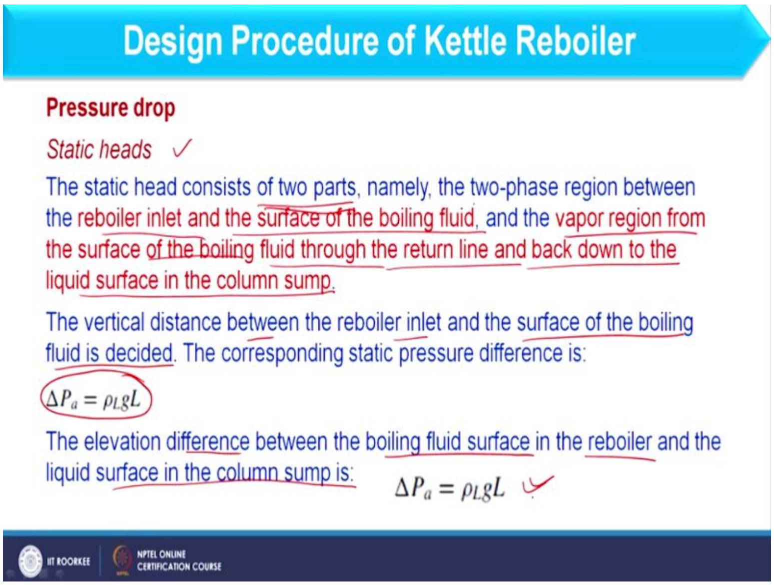

The static head consists of two parts such as reboiler inlet and surface of the boiling fluid. So, from the inner pipe to the liquid which; is available in the reboiler. So, from the inlet pipe to liquid which; is available in the reboiler because liquid will stay there. So, it will put some static head and further vapour region from the surface of boiling fluid through the return pipe and back down to the liquid surface in the column sump.

So, from upper layer of the liquid to return pipe and then to the distillation column whatever static head is there that we have to find out and that is because of vapour. So, the vertical distance between the reboiler inlet and surface of the boiling fluid can be decided. It means the height of weir plus the height of feed line. So, that can be decided and if I know that height we can find out static head using rho g L.

Further, the elevation difference between boiling fluid surface in a reboiler and the liquid surface in a column sump if I know that we can find out pressure in that section also. So, in that way we find out the static head.

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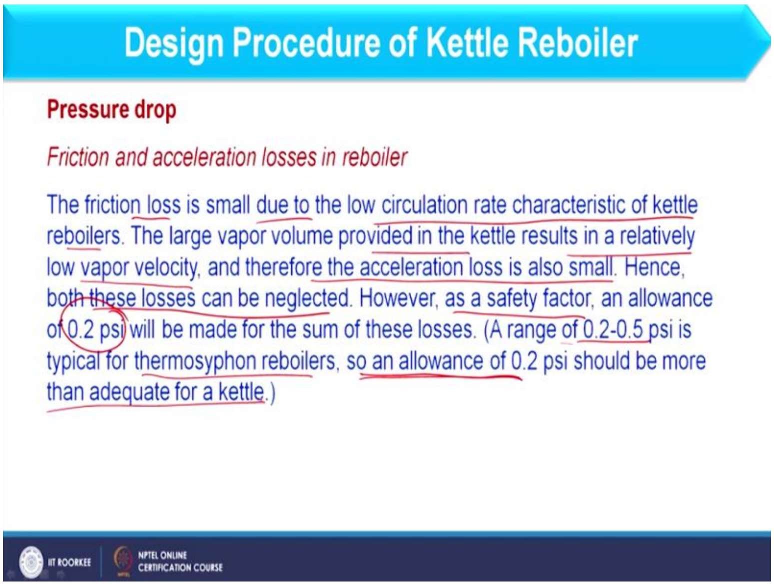

Now friction and acceleration losses in the reboiler: This we consider as the friction loss is small due to low circulation rate characteristics of kettle reboiler. The large vapour volume provided in kettle results in a relatively low vapour velocity and therefore the acceleration loss is also small. So, if we consider the friction and acceleration loss that is not significant. However, we consider that for safety purpose and we provide some losses to this section also.

However, these losses can be neglected. Further as a safety factor we consider 0.2 psi as the loss and if you see further a range of 0.2 to 0.5 psi is typical for thermosyphon reboiler so an allowance of 0.2 psi should be more than adequate for the kettle. So, in this way you have to consider friction and acceleration losses in reboiler and that will be equal to 0.2 psi and now we will see the friction loss in feed line as well as return line.

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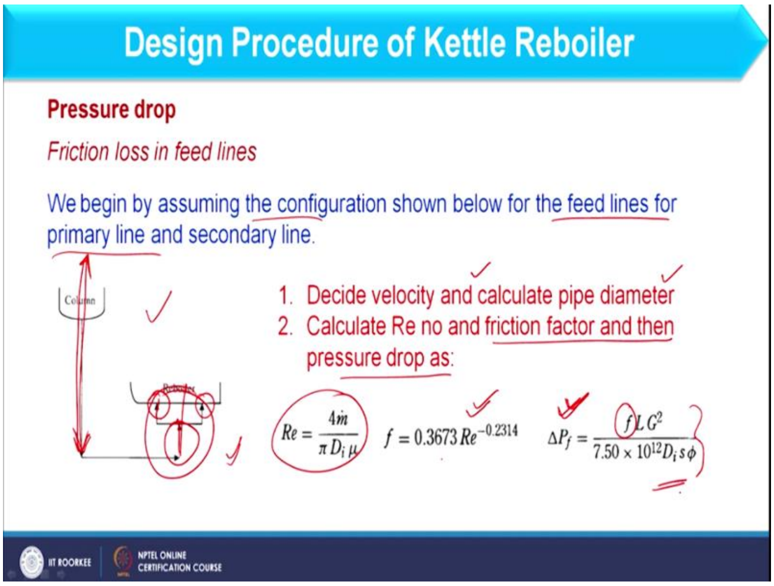

So, if you consider the feed line, feed line is basically this line because pressure drop which is available in this line that we already calculated and this we name as available head. Now, we have to find out friction loss in this. So, we begin by assuming the configuration shown here from the feed lines from primary line to secondary line. So, this is basically the primary line and these two are secondary line.

So, whatever friction loss will be there that we have to find out and to find that we have to decide the velocity and calculate pipe diameter. So, which pipe diameter this primary and second line diameter and after that once I am having the velocity we can find out Reynolds number and friction factor we can consider as like this. So, here I am having the Reynolds number we can find friction loss.

And once I have the friction loss we can find out frictional loss in feed line all these parameters you know already this expression we have used in double pipe heat exchanger design. And as we have discussed friction loss in feed line we will further discuss friction loss in return line.

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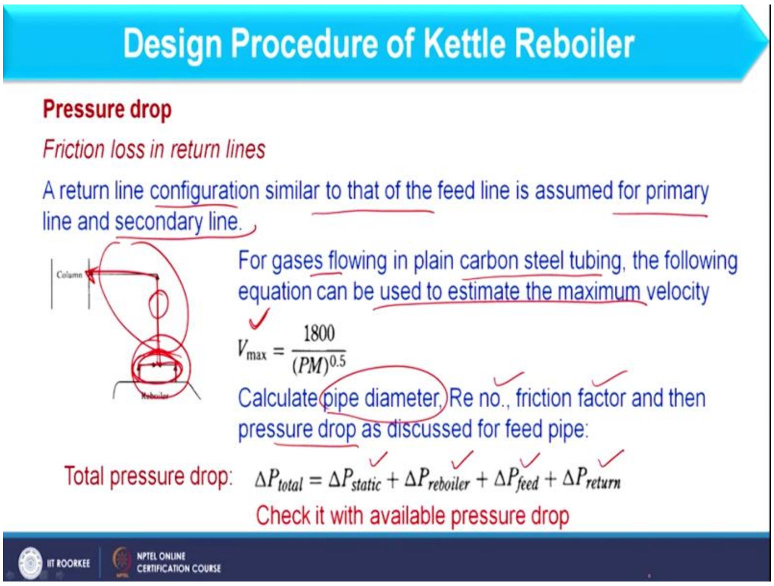

So, as far as return line is concerned again we have the nozzle from this vapour exits and it combinedly enters into the column so this is basically return line. So, the return line configurations similar to that of feed line consider primary as well as secondary line. So, this is basically secondary line and this is the primary line. In this case, we have gases not the liquid.

However, in feed side we consider liquid only, but in return line we should consider gas only. For gases flowing in a plane carbon steel tubing the following equation can be used to estimate maximum velocity so that you can obtain from this expression and further we will find out the pipe diameter, Reynolds number, friction factor and then the pressure drop as we have calculated for feed pipe.

So, in this case total pressure drop available in feed line in the boiler itself and the return line we can find as delta P total should be equal to delta P static, delta P reboiler, delta P feed and delta P return and all these pressure drop that is delta P total should be less than available pressure drop in the column. So, in this way we complete the design of kettle reboiler.

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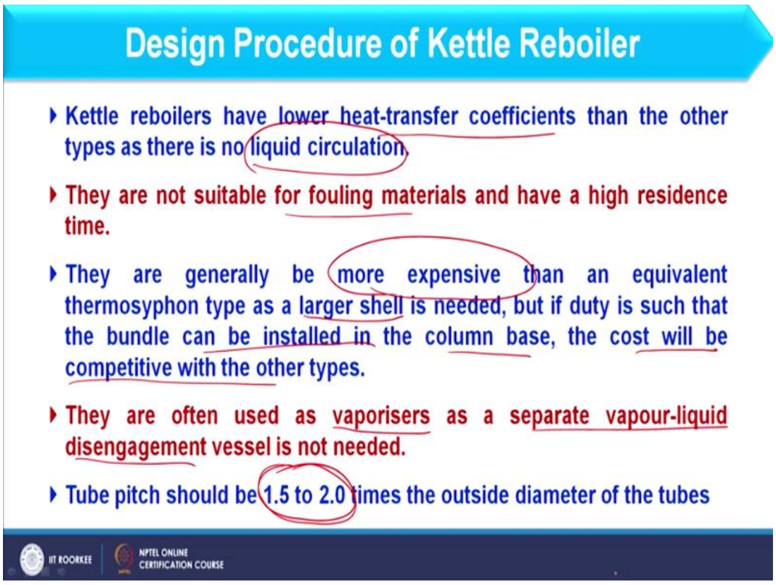

Now, we will discuss few more points about kettle reboiler. The kettle reboiler has low heat transfer coefficient than the other type of reboiler because there is no liquid circulation. When the liquid circulation will be there we can maintain high velocity and it give high heat transfer coefficient. So, as we also discussed previously that kettle reboiler are not suitable for fouling material because it has more residence time.

They are usually more expensive than the equivalent thermosyphon reboiler because it includes larger diameter shell, but if the duty is such that the bundle can be installed in the column base the cost will be reduced significantly and usually kettle reboilers are used as vapourizer as it has a vapour liquid, separation section along with vapour generation section and as far as tube pitch in kettle reboiler is concerned so that 1.5 to 2 times tube OD.

So, if you see here we are having larger pitch in comparison to shell and tube heat exchanger and the reason behind this is that because it has more residence time, it has more tendency to foul. So, for cleaning purpose if I am providing larger space between tubes it will be easier. So, because of that we consider different pitches in comparison to 1.25 d 0. So that is about kettle reboiler design.

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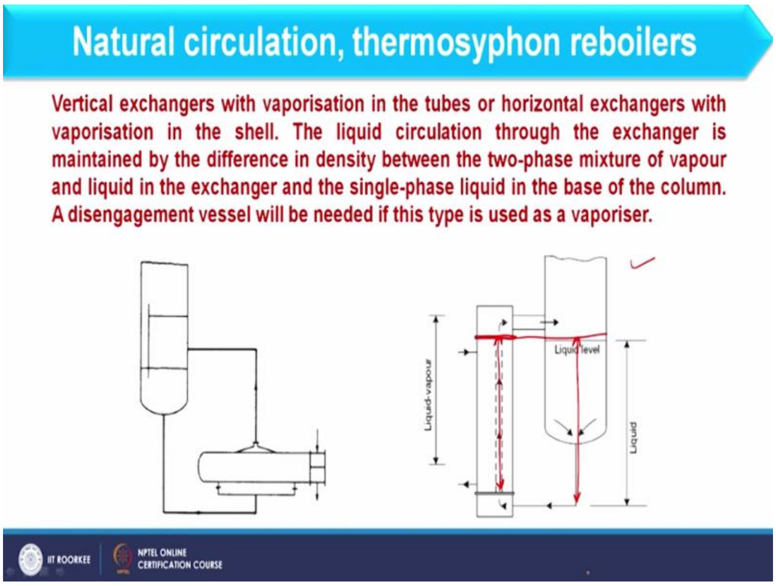

And now we will focus on natural circulatiton and thermosyphon reboiler. So, if you see we have already discussed these images where if I have to install thermosyphon reboiler horizontally we should consider shell side boiling and if I have to install thermosyphon reboiler vertically boiling should take place inside the tube. So, these two combinations we can have.

Now here we will discuss few more points about thermosyphon reboiler which is placed vertically. So, just focus on this schematic if I consider top tube sheet like this the alignment of this tube sheet should be in level of liquid available in distillation column. So, if I consider this total length of the tube the liquid level available in distillation column will be similar to that.

I am not saying it is equal to that, but it will be almost same to tube length. So, this we carry out because we provide natural circulation and for that we have to consider significantly long pipe and that long pipe depends on the tube length. So, here we will discuss few points about vertical thermosyphon reboilers as well as horizontal thermosyphon reboiler.

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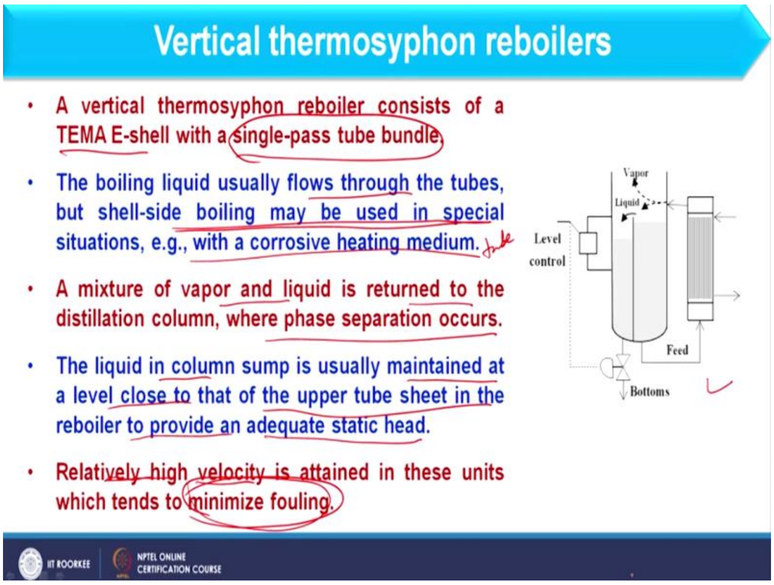

So, as far as vertical reboiler is concerned it consists of TEMA E-shell with single pass tube bundle. So, here you should keep in mind that passes in vertical thermosyphon reboilers are only one, one shell and one tube pass and that is quite obvious also because whatever vapour is generated it should move up, it should not move here and there in the exchanger and so the circulation cannot be maintained.

Further, boiling liquid usually flows through the tubes, but shell side boiling may be used in special condition where I am having corrosive heating media. So, heating media should be allocated to tube side. A mixture of vapour and liquid is returned to the distillation column where phase separation occurs. So, in this reboiler phase separation between vapour and liquid is in distillation column itself not in the reboiler.

Further, if you see liquid in a column sump is usually maintained at the level close to that of upper tube sheet in the reboiler to provide an adequate static head. So, this point we have already discussed so that is basically vertical thermosyphon reboiler where feed is entering to the tube side and so it relatively handles high velocity in comparison to kettle reboiler and because of this scale formation can be minimize. So that is the added advantage of vertical thermosyphon reboiler.

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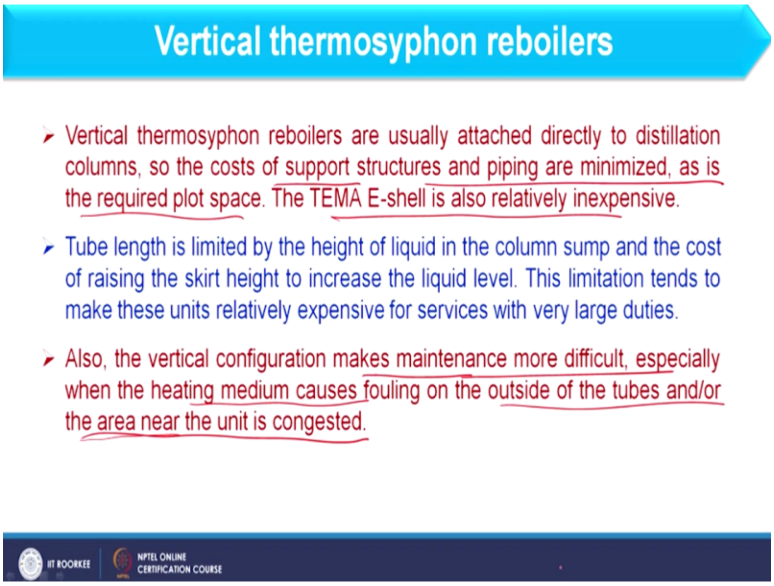

So, vertical thermosyphon reboilers are usually attached directly to distillation column. So, the cost of support structure and piping are minimized as is required plot space. So, usually these types of reboilers are attached to distillation column and we consider TEMA E-shell which is relatively inexpensive. So, vertical thermosyphon reboiler capital investment is not significant because we provide support with the distillation column.

And we use TEMA E-shell which is the cheapest type of shell. However, if I consider vertical configuration maintenance is not easy in that case because it is placed vertically and especially when heating medium causes fouling on the outside of the tubes and or the area near the unit is congested. So, that we also have to keep in mind that vertical thermosyphon reboiler maintenance is and cleanliness is not easy.

However, it has some advantages also and therefore these are used significantly. Now we will focus on horizontal thermosyphon reboilers.

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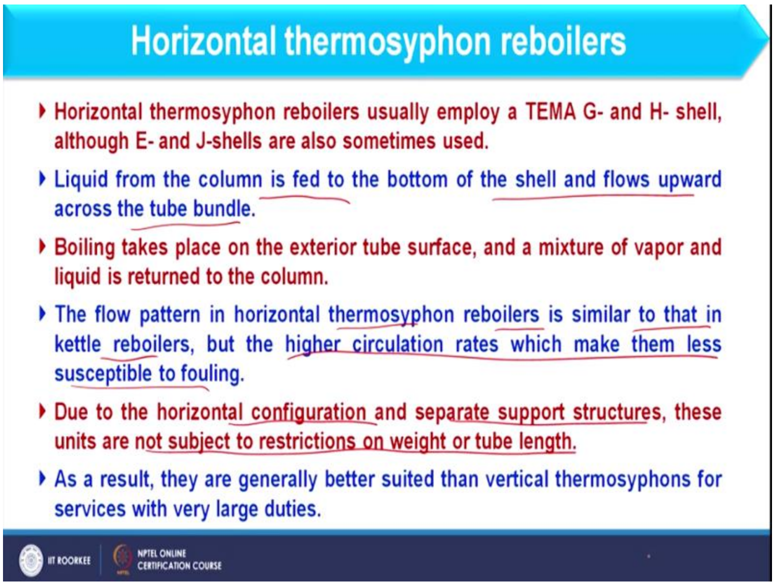

As far as horizontal thermosyphon reboilers are concerned these usually consider TEMA G H shell along with E and J shell. E shell you already know this is basically G shell and here we have this H shell and this is basically J shell and liquid for the column is fed to the bottom of the shell and flows upwards across the tube bundle. So, this you already know if horizontal placement is there boiling should be in shell side.

So, flow pattern in horizontal thermosyphon reboiler is similar to that in kettle reboiler, but high circulation rates which make them less susceptive to fouling. So, the placement of kettle reboiler as well as horizontal reboilers are same, however, we have added advantage in horizontal thermosyphon reboiler that it has less fouling in comparison to kettle reboiler, but kettle reboiler has added advantage because it consider vapour liquid, separation section along with vapour generation.

So, that is not the case with vertical thermosyphon or horizontal thermosyphon reboiler and now we have an important point that because of horizontal configuration separate support structures these units are not subject to restriction on weight or tube length. What is the meaning of this? It means that when I consider horizontal thermosyphon reboiler its support we can provide separately it is not connected with the distillation column.

So, if horizontal placement is there we can provide more and more support, easy maintenance will be there and this type of reboiler includes very high duty. So, if heat duty is large reboilers can be placed horizontally. So, as far as large heat duty is concerned horizontal thermosyphon reboiler are more acceptable in comparison to vertical thermosyphon reboiler so that is the advantage of this type of reboilers.

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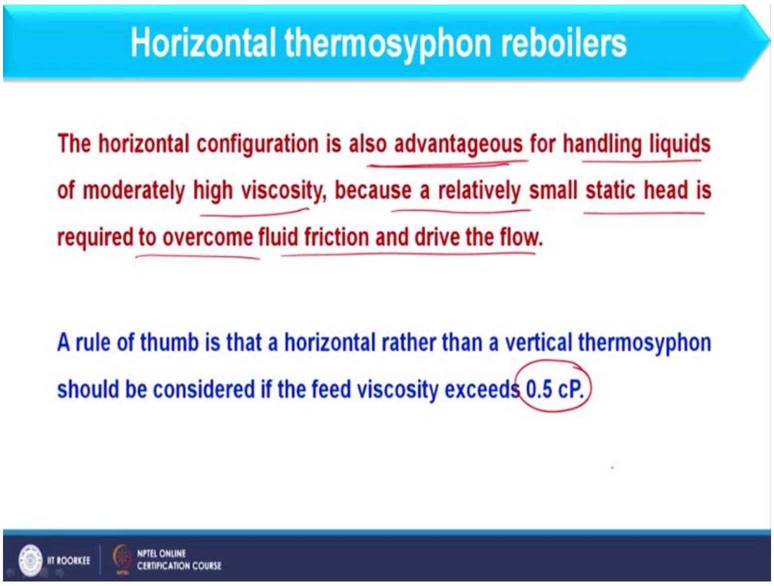

So, we have few more points about horizontal thermosyphon reboiler that horizontal configuration is also advantageous to handle liquid of moderately high viscosity because a relatively small static head is required to overcome fluid friction and drive the flow. When I consider horizontal thermosyphon reboiler it has less travelling distance by the fluid in comparison to vertical thermosyphon reboiler because vertical thermosyphon reboiler it has to travel the total length of the tube.

However, in horizontal thermosyphon reboiler it has to only enter into the shell side and if it is horizontally placed we should not provide much long pipe when it is connected from distillation column bottom to reboiler. So, we can consider slightly viscous liquid in horizontal thermosyphon reboiler in comparison to vertical thermosyphon reboilers and if you see the thumb rule we use horizontal thermosyphon reboiler when viscosity exceeds 0.5 centipoise. So, you can choose thermosyphon reboilers accordingly.

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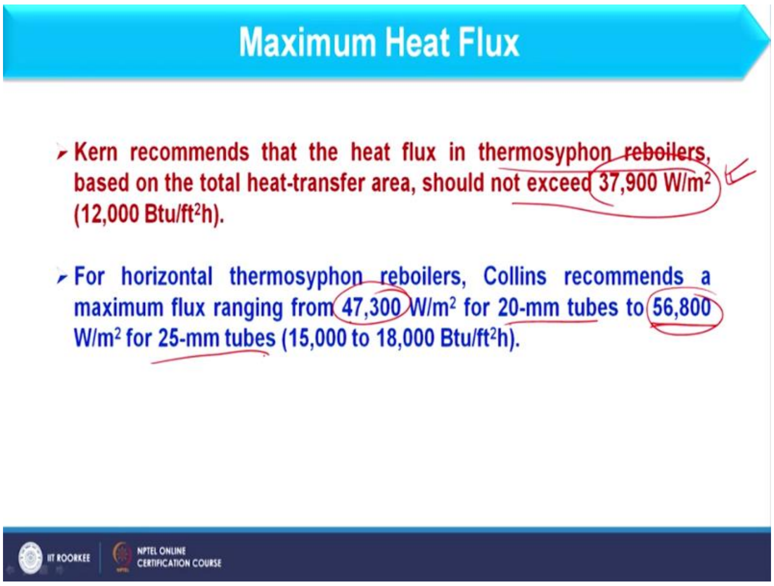

And now we will focus on the maximum heat flux because to start design of thermosyphon reboiler we should focus on maximum heat flux. Because heat flux whatever is available in the system should not exceed. So, what is the maximum limit of this? As far as thermosyphon reboilers are concerned Kern recommended that the heat flux should not exceed 37,900 watt per meter square.

So we should take this value to start the design and this value is available for vertical thermosyphon reboiler. However, for horizontal thermosyphon reboiler, Collins recommended a maximum range is available from 47,300 to 56,800 and this value is available for 20 mm tubes and this value is available for 25 mm tubes. So, in this way you consider the maximum heat flux while designing horizontal as well as vertical thermosyphon reboiler.

And in the next lecture, we will discuss design of vertical thermosyphon reboiler in detail and which will be started considering maximum heat flux which we have just discussed. So that is all for now. Thank you.