Process Equipment Design
Prof. Shabina Khanam
Department of Chemical Engineering
Indian Institute of Technology – Roorkee

Lecture –11
Exchanger Shell

Hello everyone. Welcome to the third week of the course Process Equipment Design and here I am discussing 11th lecture of this course and this is basically the first lecture of week 3 and here I am discussing exchanger shell. Now, if you remember the last lecture we have discussed the tubes and which is under constructional details of shell and tube heat exchanger and here we are discussing the constructional details of shell side of a shell and tube heat exchanger.

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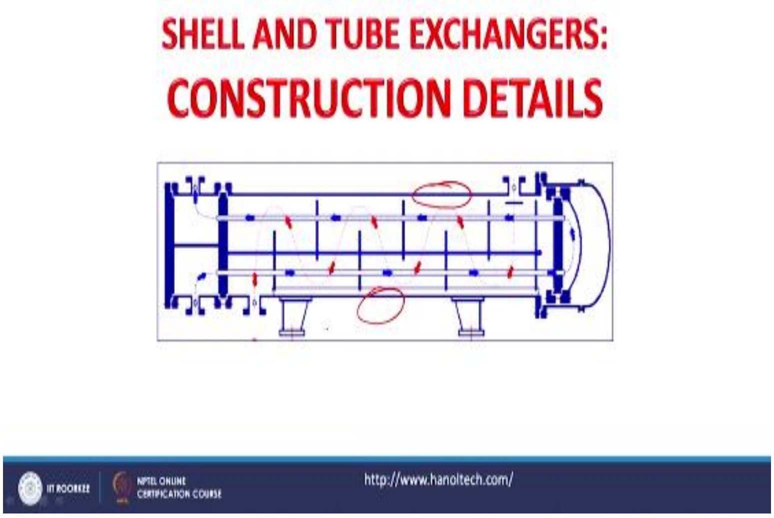

So, let us start this lecture. So, if you see the constructional details of a shell and tube heat exchanger we are basically going to discuss the shell side of shell and tube exchanger and how the construction is made in shell side. So before starting that, we will first define that what is a shell?

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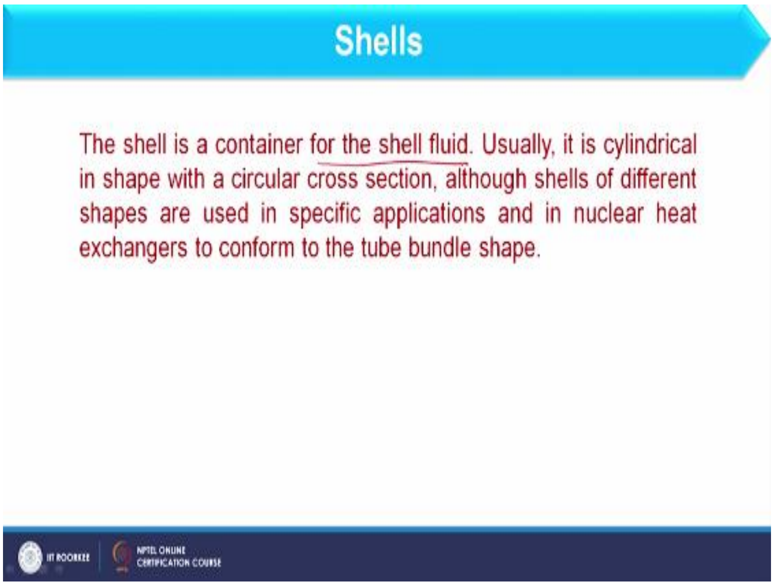

So, if you see shell is a container for the shell fluids because here we have to distinguish the fluid according to the shell and tube side. So, this is basically the container where shell fluid moves. So, it is basically cylindrical in shape and when we consider the cross-sectional view of the shell it looks like a circular shape. However, in different application we have also other shapes of shell such as when we consider the boiler how the boiler looks like.

Boiler is basically rectangle in shape. So, when we consider its shell it is basically rectangle and at the inner periphery of the boiler we have water tubes. So, in that case shell is not cylindrical. In the similar line in nuclear heat exchangers the shell is different than the circular or the cylindrical and how we decide the shape of the shell? It will depend on the shape of bundle and as far as material of construction is concerned usually shells are made of carbon steel.

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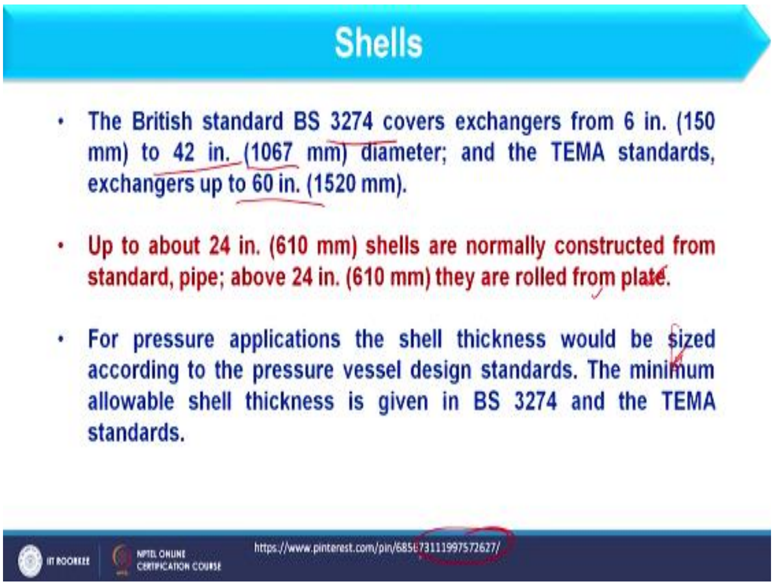

And as far as its dimension is concerned when we see the standards such as British standard BS 3274 which covers shells from 6 inches to 42 inches where in mm it is 150 to 1067 mm. So, this is basically the diameter of the shell and according to TEMA standards up to 60 inch shells are available in shell and tube heat exchanger. So, when we consider the shell diameter up to 24 inches shells are normally constructed from the standard pipe.

It means whatever pipes are available in the market those pipe you can consider as a shell, but it has the limitation that it is available maximum up to 24 inches. If you have to consider shell beyond that you have to make it by rolling a metal plate and how the rolling of the metal plate is done that you can see from this image. So, here you can see the cylinder this is one cylinder, second cylinder and below this we have another cylinder which is available here.

So in between these three cylinders metal sheet is pressed and because of the movement of this cylinder the rolling takes place. So that you can understand from this image, if you want to study that in detail this is the link for this. So in this way we prepare the shell through rolling. Now, if I say that shells is available in a particular diameter where pipe shell is also available and plate shell is also available.

Pipe shell if I am saying it means pipes are already available in the market and if I am saying plate shell it means you have to roll the plate and prepare the shell. So, if the diameter is equal in both the cases pipe shell becomes cheaper in comparison to plate shell because of money involved in this rolling process and that is the expensive process. So, if choice is available and your diameter is lying between both shell that is pipe shell and plate shell you should choose the pipe shell.

And as far as shell thickness is concerned that you can calculate through mechanical design where pressure vessel design is discussed either it is standard of Indian code or it is a British standard code whatever. So in that way you can calculate the thickness and how we should choose the correct shell diameter that I have already discussed, but first of all we have to find to calculate the shell diameter.

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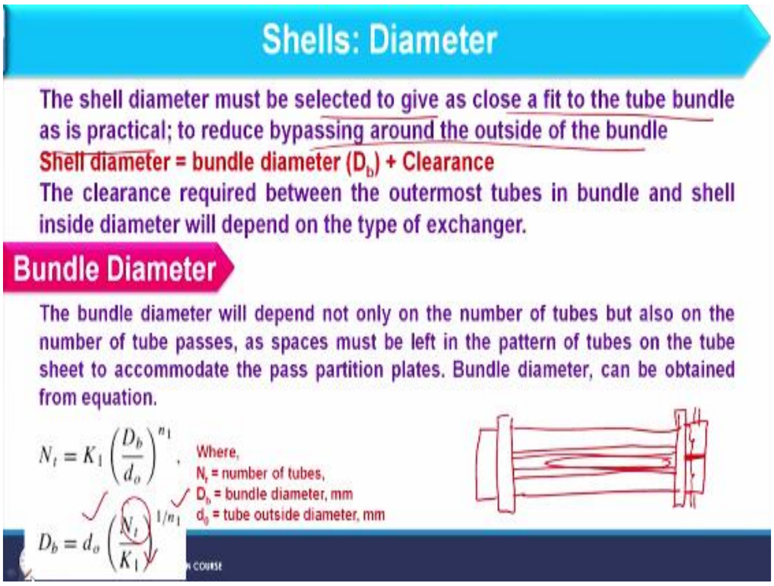

So, when I am considering the shell dia the shell dia must be selected to give a close fit to the tube bundle as is practical to reduce bypassing around the outer side of the bundle. So, actually what will happen when we select the diameter we have to be very careful while deciding the space which is available in outer layer of the bundle and shell inside dia. Now, if you remember the classification of shell and tube heat exchanger.

We have discussed that clearance is maximum in internal floating head because the whole tube sheet tube is lying within the diameter of the shell. So in that case clearance is very large. So once I am having the large clearance I have to invest a lot in shell diameter. So, whatever region is available region means the gap or the clearance between outer layer of the bundle and the shell inside diameter that section we call at bypass section.

So, we should avoid that bypass section and therefore we have to select the diameter of the shell so that it gives tight fitting with the bundle. So, the shell diameter you can calculate which should be equal to bundle diameter plus clearance and clearance will depend on the type of heat exchanger along with the bundle dia. So depending upon the type of exchanger let us say if I consider internal floating head their clearance must be very high in comparison to fixed tube sheet or U tube like that.

So that part we will discuss in detail in the next slide, but before that we have to calculate bundle diameter as shell diameter depends on the bundle diameter. Now, if I consider the bundle diameter on which parameter bundle diameter should depend. The first is number of tubes. Second is how the tubes are arranged in the tube sheet either it is a square pitch, triangular pitch or in other manner also.

And apart from this it will also depend on the tube passes. You see bundle diameter we are calculating to calculate the shell diameter so I am just focusing on shell diameter, but it will depend on the partition plate which we are making or which is available in tube side not in shell side. So, in all these parameters the bundle diameter depend. Now considering these if you see we can calculate bundle diameter using this equation where d 0 is the outer diameter of tube N t is total number of tube irrespective of the passes.

And K 1 and n 1 are the parameters which depend on the type of pitch and the number of passes. So, here I am having triangular pitch as well as square pitch in both case pitch is 1.25 into d 0 and number of passes vary 1, 2, 4, 6 and 8 as you understand that these passes belong to the tube passes not the shell passes. So, my point is you should understand that bundle diameter depends on number of tube and how the tubes are arranged.

But why it will depend on the pass partition plate because that is not available in shell side. So, to illustrate that we will first focus on the exchanger this is the simple exchanger this is the tube sheet and here we will the inlet and outlet nozzle. Now, what will happen pass partition plate is usually available in tube side and which is this. However, I am considering this plate and based on that I am deciding the bundle dia.

And the reason is when I am dividing this tube side flow what I am doing I am dividing number of tubes in these two manners, in these two sections. So, what will happen whatever plate is available just corresponding to that side in tube there if I consider tube will be available like this and like this. So this is one tube, this is another tube.

So, if you consider this pass partition plate corresponding to this the space in shell is empty because no tube is lying in that region and therefore whatever liquid is available it will be like liquid is available in dead zone. So, wherever I am having the pass partition plate in tube side corresponding to that no tube is available in shell side and we have to keep that space empty and therefore the bundle diameter increases if we keep on increasing the passes.

So, because when we increase the pass we basically increase the number of partition plate and therefore the corresponding space I have to keep empty in shell side. So, it will depend on all three parameters that is number of tubes arrangement and the tube passes basically. I hope you understand this.

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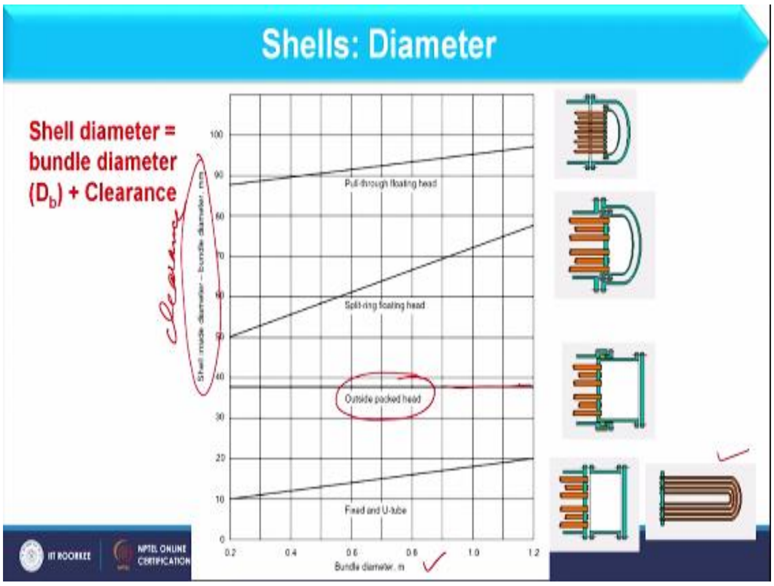

So, once I am having the bundle diameter I have to calculate the clearance and that clearance you should understand it is basically the distance or it is basically the difference between bundle dia and shell inside dia. If, I am speaking about shell dia I mean it is shell inside dia not the outside dia. So, here I am having the graph where different shell and tube heat exchangers are available.

And accordingly we can have shell inside dia minus bundle dia it means this is basically the clearance and here bundle dia is shown. So, depending upon the type of shell and tube heat exchanger we can have the clearance. So, bundle dia and the type of exchanger both. So here we have the fixed tube sheet and here we have the U tube. So, accordingly we can see the clearance.

Similarly, for outside packed bed means external floating head. So, external floating head has nothing to do with the bundle dia. So in this case the clearance does not depend on the bundle dia. However, if I consider split ring floating head as well as internal floating head the clearance depends on the bundle dia as well as the type of exchanger. Now here you can argue that why it depends on bundle dia.

It should only depend on the type of exchanger because what we are doing basically we are trying to take the bundle out. So it means we have to insert the bundle as well. So, when we are inserting this we should provide sufficient space in the shell. So, it will depend on the type of exchanger as well as the bundle diameter because if bundle diameter is high or if the bundle diameter is large we have to insert it carefully inside the shell.

And so the space requirement will be high. So except external floating head because there I am not inserting the bundle in the shell completely because the tube sheet remains outside and floatation remains outside so it will not depend on the bundle diameter. So except that for all heat exchanger the clearance depends on type of exchanger along with the bundle dia.

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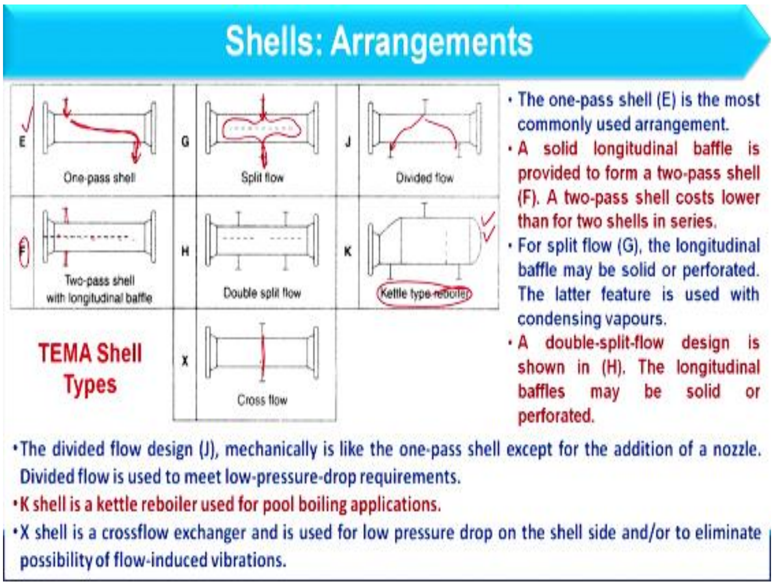

And here we have some of the arrangement of the shell as we have discussed arrangement of the tubes and this is as per TEMA standards. So, we have different nomenclature for each type of shell arrangement the simplest one is type E where it will be only one pass where fluid is entering from one pipe and exiting from another pipe from another side. So, it completely travels the length of the exchanger and then exits from the another side so that is the simplest type shell.

Next, we have TEMA F shell and here you can understand the inlet and outlet both nozzle are at the same side. So here we will put this partition plate so if I am putting the partition plate in shell basically that is horizontal baffle and both side of baffle is welded at inner surface of the shell. So, in this baffles sometimes holes are provided. So, these holes basically work for condensation process when the liquid is flowing the holes are not required over the baffle.

However, holes are required or we can call that as perforated baffle. So through this perforation condensate of the vapor can pass through easily. So, in that case if I consider TEMA F shell it means that is two pass in a shell as we consider the passes in tube we consider passes in shell by providing baffles and next we have TEMA G shell. So, if you see the TEMA G shell here we split the flow.

Inlet and outlet nozzle are at the one line or these are aligned. So, fluid which is available it is divided in two and then travels like this and then travels like this and then it exits. So this is basically the split flow shell and similarly we can have the TEMA H shell where two splits are required and we have TEMA J shell where the fluid is divided in two parts like this or this and this is basically done to reduce the pressure drop.

And after that we have kettle shell or that is the TEMA K shell that we consider as kettle type reboiler. So, this we will consider in detail when we will design the kettle reboiler and then finally we have cross flow fluid is simply pass through these tubes and exits. So, in this way we have different types of shell arrangement.

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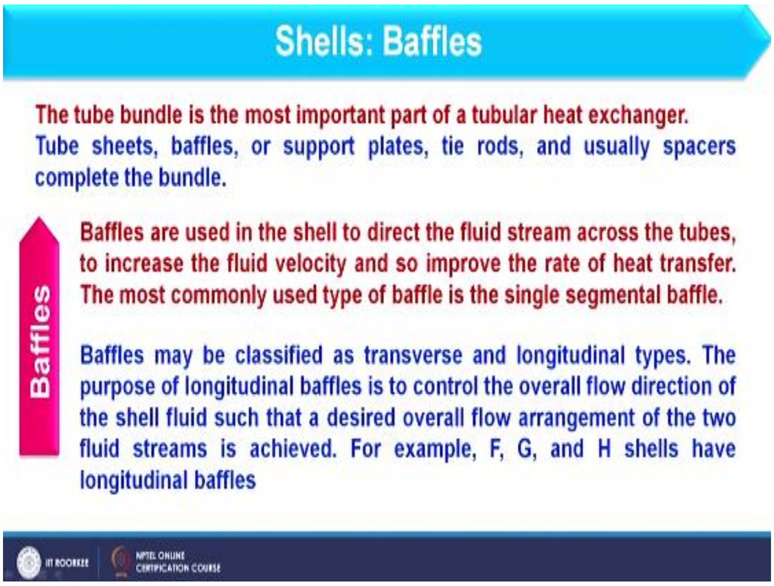

Now we will focus on baffles. So, when I consider the baffles, baffle is an important part of a tube bundle and apart from that what are the different parts which are available in tube bundle and these are basically tube sheet baffles, support plates actually when I consider baffle this we also called as support plate because these are used to hold the tubes along the length. So, apart from this tie rods and spacers are also a part of bundle.

So, here we will discuss the baffles. Now what is the purpose of baffles we have already discussed that it basically direct the fluid in shell side and depending upon the baffle design we can control the pressure drop, we can control the heat transfer in shell side. So, we will discuss different types of baffle however most commonly used baffles are single segmental baffles.

Now as far as position of baffles are concerned these are two types. If you remember TEMA F shell or split flow shell so in that case what you have observed? You have seen that baffles are placed along the length. So, that is basically longitudinal position and when I am considering baffles as a support plate to hold the tubes and to direct the fluid in shell side we usually arrange that in transverse way which is perpendicular to the tubes. So, these are basically two position for the baffles.

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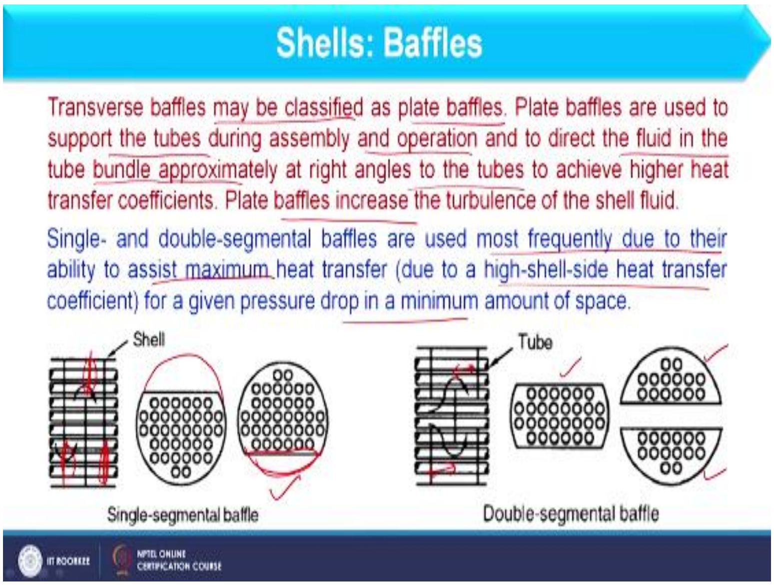

So as far as transverse baffles are concerned that may be classified as a plate baffles and these baffles are used to support the tubes during assembly and operation and to direct the fluid in tube bundle at right angle to the tubes to achieve higher heat transfer coefficient. So, plate baffles are usually used to increase the turbulence in shell side and as far as baffles are concerned we have single segmental and double segmental.

And these are most frequently used due to their ability to assist the maximum heat transfer, due to high shell side heat transfer coefficient for a given pressure drop in a minimum amount of space. So, we have single segmental baffles, segmental baffle means which has a cut if I consider the complete baffle some section is removed from this. So, you can consider this section as well as this section.

So the section in the bundle which is available between baffle tip and the shell like this. So this section we call as window zone and here we have double segmental baffles where you can consider we can have three set of each baffle. One is at the center and another section is available at top and bottom, but after some distance baffle spacing is kept between these. So, these are basically double segmental and this is the single segmental baffles.

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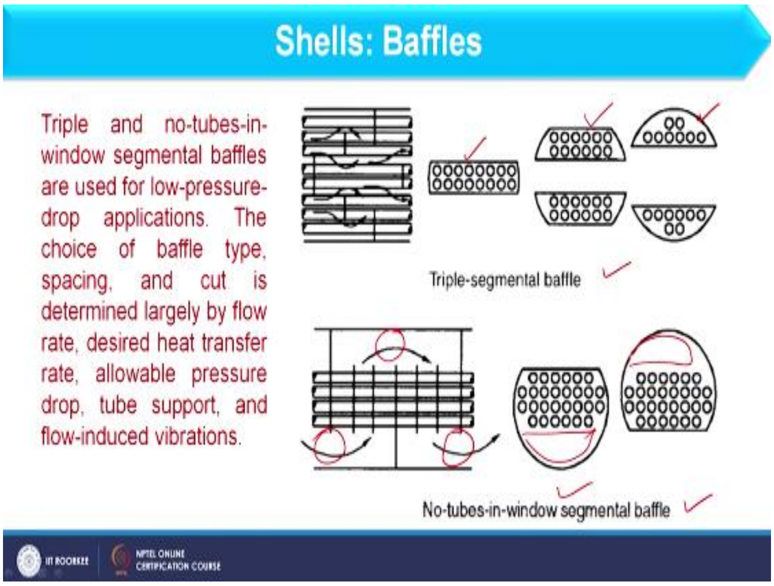

Apart from this we have triple segmental baffles also and no tube in window segmental baffle. So, triple segmental baffle we have three different sets. One set is this then slightly larger and then the larger diameter, so we have triple cut over here. So, we consider as triple segmental and here we have no tube in window as I have told you this is basically the space which we call as the window zone so no tubes are available in window zone.

So, accordingly we can make the cut. It means no holes are available in this section which I am calling as the window zone and these are used basically to reduce the pressure drop and further we have another type of baffle which we call as disk and doughnut baffle.

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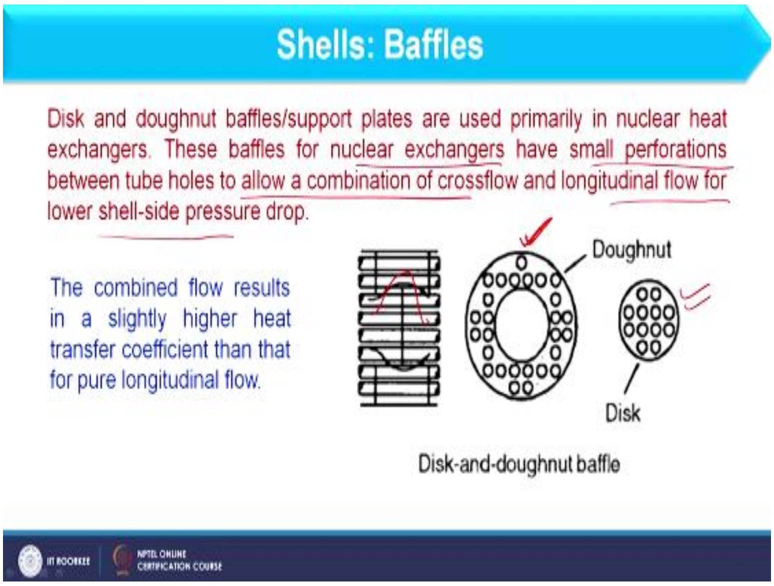

So you can consider this is basically the disk so you can consider this is basically the doughnut and this is the disk. So, we can place this accordingly and we can obtain the desired pressure drop and heat transfer coefficient. So these baffles are used in nuclear exchangers which has small perforation in tube holes to allow a combination of cross flow and longitudinal flow for lower shell side pressure drop.

So in between also it has a hole, so that fluid can pass through these holes and move longitudinally along with the cross flow like this. So, these are different types of baffles now as far as this course is concerned we will only focus on segmental baffles.

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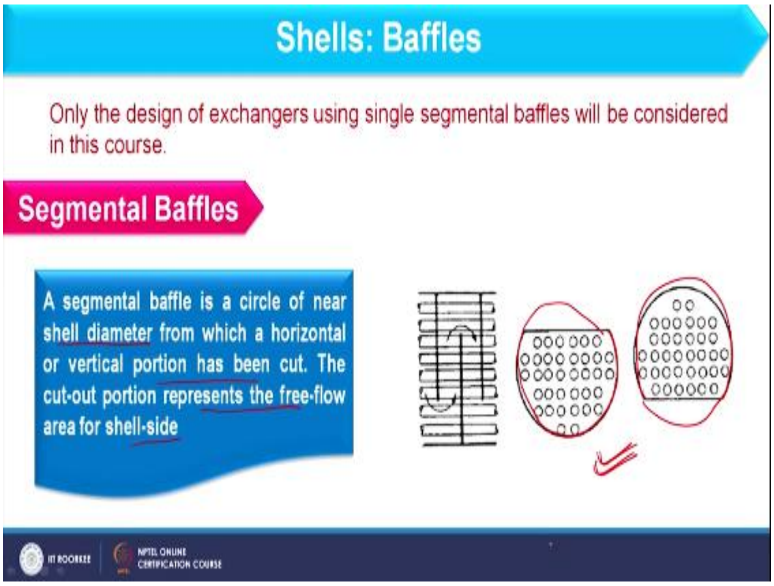

So as far as segmental baffles are concerned segmental baffles is a circle of near shell diameter from which a horizontal or vertical portion has been cut. The cutout portion represents the free flow area for shell side. So, we have this cut as well as this cut this we are considering as segmental baffle or single segmental baffle. So, only this type of baffles we are going to design in this particular course.

And if I ask you what should be the diameter of this baffle? This diameter will be slightly lesser than the diameter of the shell because this baffle is usually inserted in the bundle and complete bundle is further inserted in the shell. So, the baffle diameter should be such that is should be properly inserted in the shell and therefore its diameter should be slightly lesser than the inner diameter of the shell.

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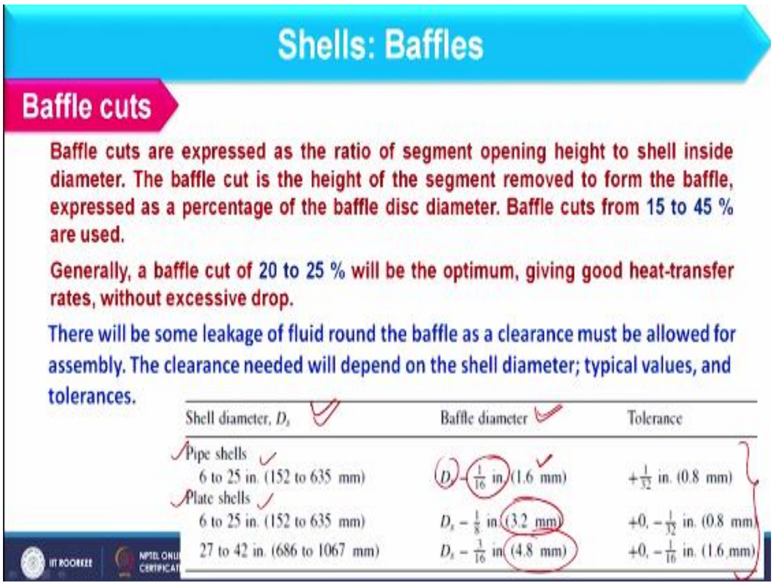

Next point is how much cut we have to keep in segmental baffles. Usually cut varies from 15% to 45%, but it is not continuous like 15, 16, 17 it is not we have some standards also. However, when we consider optimum cut that is usually 20% to 25% which gives sufficient heat transfer coefficient without having excessive pressure drop. So, as I have discussed that baffle diameter is slightly lesser than the shell diameter.

It means there must be some space between shell dia and baffle. So, that section that gap basically works as a leakage where liquid is available, but it will not participate in heat transfer. So, because of that leakages we have pressure drop in shell side. So, what that gap should be? So how much that gap should be? That we can see through a table which is shown over here.

You can see here I am having shell dia and the baffle dia. So, here I am having pipe shell as well as plate shell so if you consider 6 to 25 inches we have pipe shell as well as plate shell both and here we have the baffle dia so D s – 1 / 16 inches so this 1 / 16 inches is equal to 1.6 mm. So, this is basically the gap between shell dia and baffle dia and similarly if I consider plate shell we can have 3.2 mm gap and beyond that we can have 4.8 mm gap.

So, this table we will use when we will consider the leakages in shell design and here we have tolerance values. So in this way you can find out the baffle diameter.

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Now, next point is baffle spacing the complete range of baffle spacing varies from 0.2 to 0.1 into shell diameter. So, this is the complete range. However, the optimum spacing is lying between 0.3 to 0.5 times the shell diameter. So to start the calculation initial assumption you can take as 0.3 into shell dia as baffle spacing and where it will be required that also I will discuss. Next, is the tie rods and spacers.

Spacers is basically the distance between two baffle and it will depend on the baffle spacing. So depending upon the baffle spacing you can choose the spacers. However, tie rod will depend on the diameter. So, tie rods usually hold the baffle in a place with spacers because spacers we insert in rods not in tubes and occasionally baffles are welded to the tie rods and spacers.

And occasionally baffles are welded to the tie rods and in that case spacers are eliminated, but that is permanent connection that you cannot replace for replace for maintenance purpose. So as far as tie rods are concerned we can consider four numbers of 16 mm diameter rods when exchanger diameter or shell diameter is up to 380 mm and when shell diameter is up to 1 meter you can consider 8 tie rods having 12.5 mm diameter.

So, in this way you can decide the tie rods and then we will focus on tube sheets. Now what is tube sheet what is the purpose of tube sheet? The purpose of tube sheet is it holds the tube. Now when I am considering that it holds the tubes means its thickness should be sufficient enough to hold the tubes. So, at least 25 mm thickness of tube sheet is provided.

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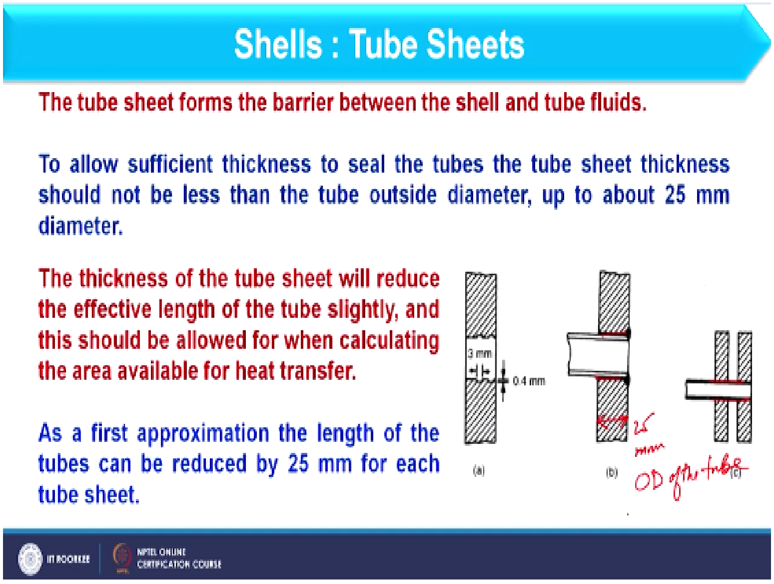

And you can see the schematic here we can this insertion of tube like this some double tube sheets are also provided. So, you can see this thickness of the tube sheet should be at least 25 mm or it will depend on the OD of the tube. So, tube sheet thickness how we can decide? Tube sheet thickness is 25 mm at least until and unless OD of the tube is less than or equal to 25.

If OD of the tube exceeds 25 tube sheet thickness should be equal to OD of the tube. So this also you will consider in designing so that it will be clear to you. So, here I am having some points about tube sheet which I have already discussed.

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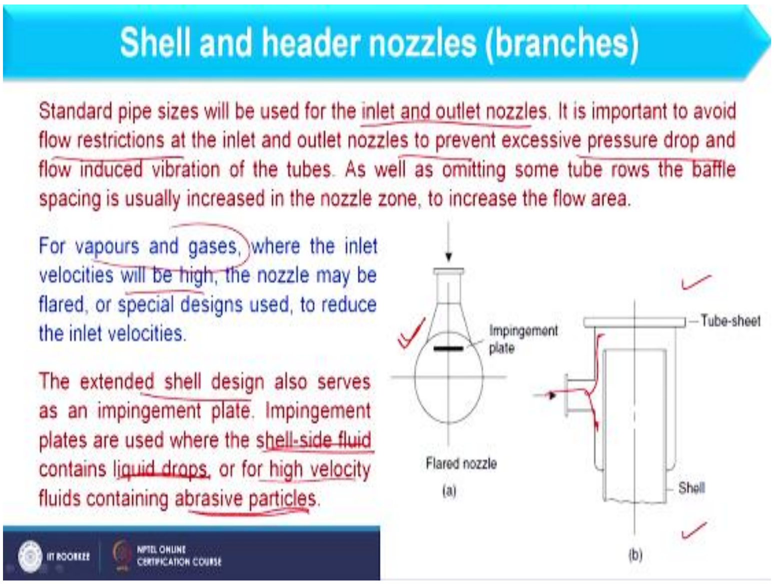

And now finally we have to focus on shell and header nozzles. So, standard pipe size will be used for inlet and outlet nozzle and it is important to avoid the flow restriction in inlet and outlet nozzle to prevent excessive pressure drop and therefore we have to consider specific design for nozzles. So, if I am dealing with vapor and gases where inlet velocity will be high the nozzle may be flared like this or special designs used to reduce the inlet velocities.

So this is one type of, this is another type of inlet where fluid is moving and pressure drop will not be significant and in some cases we consider extended shell design as shown over here which also serves as the impingement plates are used where shell side fluid contain liquid drops or for high velocity fluid containing abrasive particles so in that way we select the nozzle in shells.

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So, here I am stopping this lecture and you can find the references like this.

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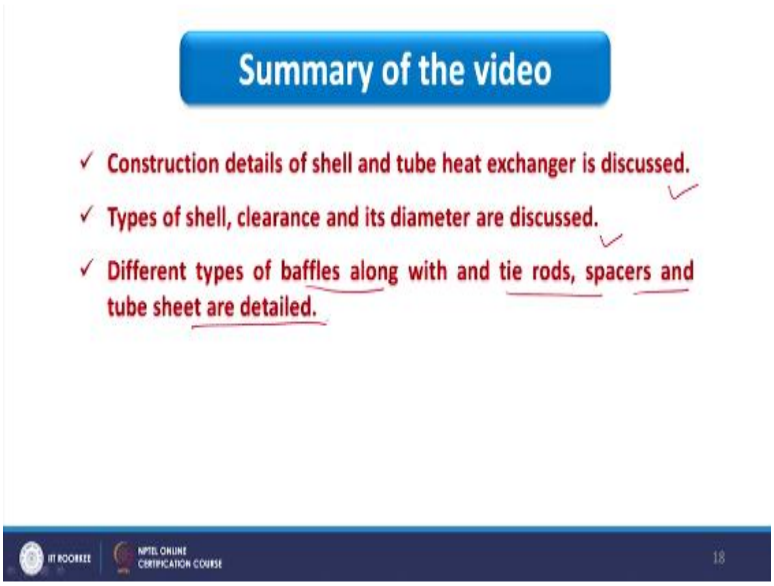

And let me summarize this video. In this video, construction details of shell and tube heat exchanger is discussed, types of shell clearance and its diameter are discussed, different types of baffles along with tie rod, spacer and tube sheets are detailed. So that is all for now. Thank you.