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

**Lecture - 09**
**Types of Shell and Tube Exchangers**

Hello everyone, welcome to the fourth lecture of week two of Process Equipment Design course, and this is basically the ninth lecture of this course, right. So here in this course, so here in this lecture, we will discuss types of shell and tube heat exchanger and this we will discuss because this information is required to design a shell and tube heat exchanger.

So first of all we will discuss the shell and tube heat exchanger and then we will discuss the operating range of shell and tube heat exchanger. And after that we will classify the shell and tube heat exchanger, okay. So let us start with the shell and tube heat exchanger. So as far as shell and tube heat exchanger is concerned, it is constructed with very large heat transfer surface where the large heat transfer surface can be accommodated in a small volume, right.

So if I consider double pipe heat exchanger, the main disadvantage is it cannot occupy, it cannot accommodate large heat transfer surface in a small volume. Because, if I consider hairpins also then the total volume of the exchanger is not small, right. So that we can, so for that purpose we can use shell and tube heat exchanger where small volume is required, but heat transfer area can be increased many folds.

And this heat exchanger can be fabricated from alloys of steel, which basically resist the corrosion.

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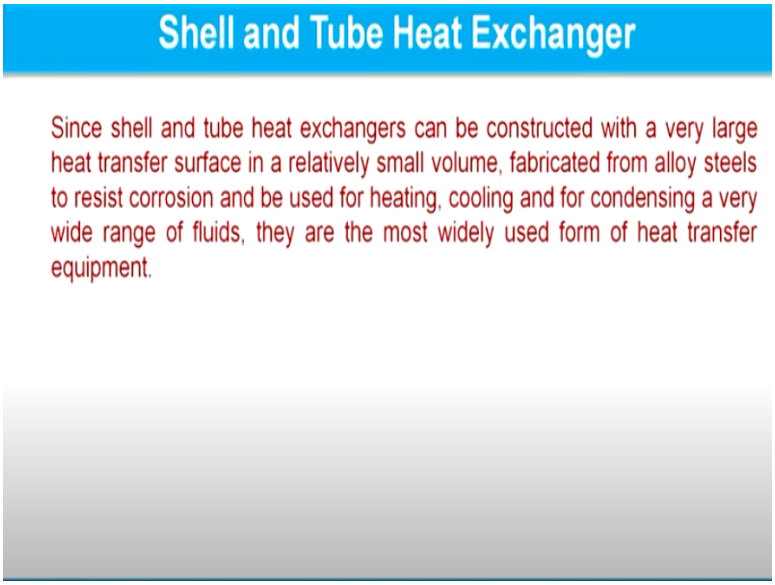


And it can be used for heating, cooling and for condensation and for condensing a very wide range of fluids. So what is the total, so what is the conclusion over here that shell and tube heat exchanger is not only used as a heat exchanger to transfer sensible heat. It is also used to transfer latent heat and therefore it can be used as a condenser and reboilers also along with the process to process heat exchanger, right.

So and because of all these advantages, these heat exchangers are most widely used in chemical plant as heat transfer equipment, okay.

Now if you consider the shell and tube heat exchanger, when we were discussing the classification of exchanger there we have discussed this heat exchanger in a very brief manner, okay, where you have understood that it can be used as a fixed tube sheet where tube sheet is attached to the shell permanently and we have the option of floating tube sheet also, right. So that is the shell and heat exchanger.

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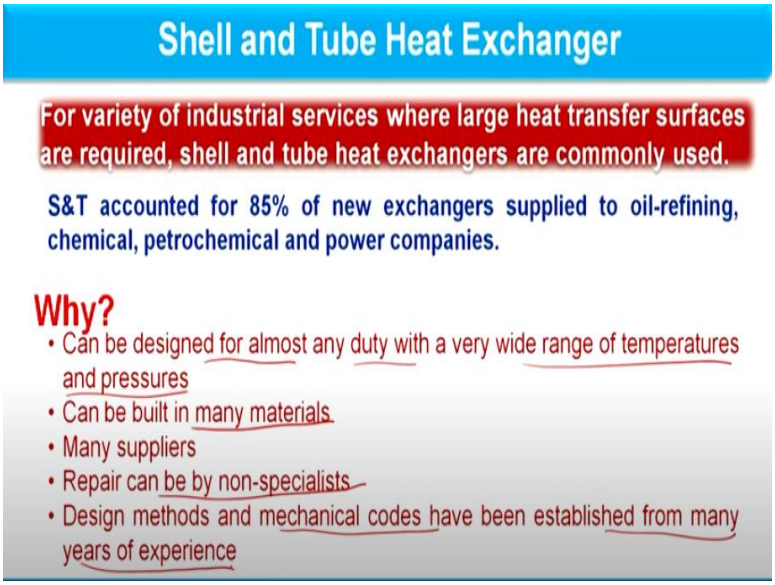


Now as far as this application is concerned for variety of industrial services, where large heat transfer surfaces are required or where large heat transfer area is required, we use shell and tube heat exchanger most commonly, okay. So as far as utility is concerned it is most commonly used heat exchanger okay.

And because of the flexibility which we have just discussed, it is used more than 85% of, it is used in most of the chemical plants and if I compare the heat transfer equipment, this heat exchangers covers around 85% of usage in oil refining, chemical, petrochemical and power companies okay. And if I ask you that why it is so? Because we just have discussed its advantage, but there are some other factors also that why it is used so commonly.

The first factor is it can be designed for almost any duty with a wide range of temperatures and pressures. In next slide we will discuss the range of temperature and pressure this type of heat exchanger can accommodate, right. So that is the reason for its wide utility because its consideration for temperature and pressure is very large, okay. Next is it can be built in many materials okay.

So material of construction which are used to make shell and tube heat exchanger are very large in number, okay. Steels are used, different steels are used and other materials can also be used, okay. Another reason is it has many suppliers, okay. If you have to check the suppliers you have to put shell and tube heat exchanger in India Mart and then you will be tired to get different calls from the suppliers okay.

So from that you can get the idea that suppliers of shell and tube heat exchangers are very large or so many, okay. And next point is repair can be done by non specialist because its design is complicated than double pipe heat exchanger but not as complicated as other heat exchangers. So it we have to open it we have to assemble it. It can be done by non-specialists of this heat exchanger also.

And we have different design methods and mechanical codes which are used to manufacture these heat exchangers from many years, because these design methods and mechanical codes are available from many years of experience. So these codes are very effective and can directly be used, right.

So you will see in subsequent lectures the codes which are used in India, which are used in British, which are used in America like that. So we have very detailed codes also in India and that is Indian standard 4305 1967. So these are used to design the shell and tube heat exchangers. But these are specifically used to design the mechanical part of that, right. Therefore, it is called as mechanical codes.

Process parameters or process design of shell and tube heat exchanger is entirely different, which we are going to discuss in this course in subsequent lectures, right. So here we have, so we have discussed different factors, which gives easy use of or easy utility of shell and tube heat exchangers in industries. And now we will discuss the scope of shell and tube heat exchanger if I focus on maximum pressure, okay.

In shell side, we can go up to 300 bar and in tube side we can move up to 1400 bar.

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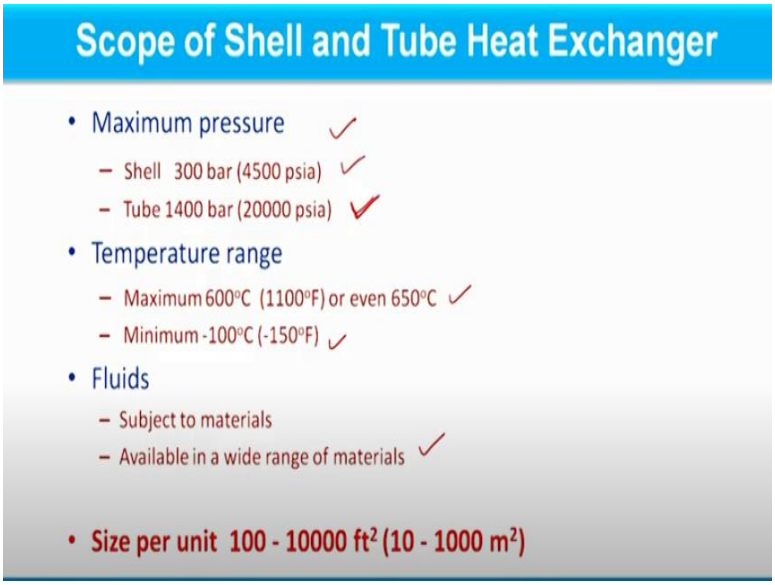


So you can see here we have very large range of pressure drop. So you can see here that we have very large range of pressure, where maximum pressure is very high. And in the similar line if I consider the temperature range maximum is 600 degree Celsius or even 650 and minimum is - 100. So complete range you see it varies from - 100 to 650 and that is huge, okay.

So you can consider the utility of shell and tube heat exchanger. As far as fluids are concerned it depends on the material. If material is available, you can use number of fluids okay, which is suitable for the material which are used to make the shell and tube okay. And then it is available for a wide range of materials, okay.

So material of construction is very large and so the fluids which are used to consider in shell and tube heat exchangers are very large in number, okay. And as far as size is concerned, its size varies from 100 to 10,000 feet square as far as area is concerned. So that is basically 10 to 1000 meter square, okay. And if you remember the double pipe heat exchanger there we have discussed the maximum area of double pipe heat exchanger is 50, okay.

But shell and tube is also available less than that, okay. So the point is, though it is available, though shell and tube heat exchanger is available, less than 50 degree Celsius, but its construction or the fabrication cost is high in comparison to double pipe. Therefore, we recommend it to use after 50 meter square heat transfer area or beyond 50 meter square heat transfer area okay, but range is available you can use.

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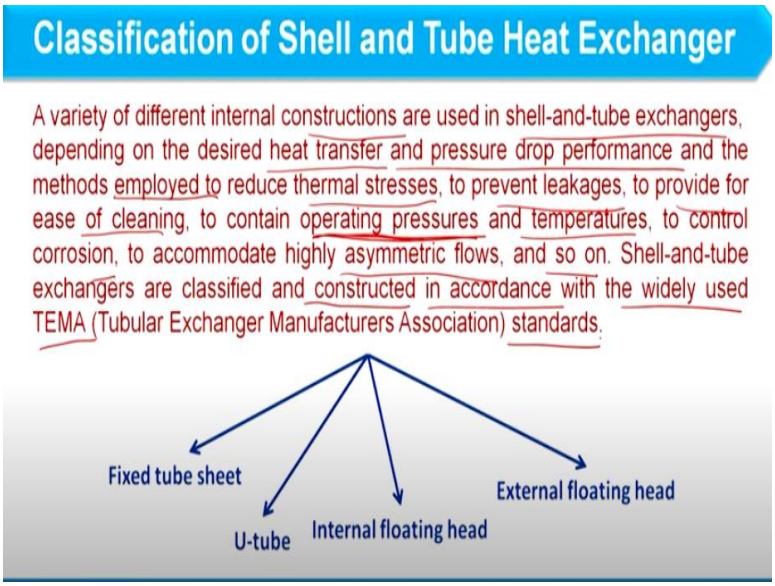


Now as far as classification of shell and tube heat exchanger is concerned we will discuss a few points and then we will start the classification. So you see the variety of different internal constructions are used in shell and tube exchanger depending on desired heat transfer and pressure drop performance, okay.

Now if you study the design of shell and tube heat exchanger, you can see that what modification we can make inside this shell and tube heat exchanger so that the heat transfer and pressure drop should lie in a permissible limit. There are a number of options, okay. So therefore, we can understand the flexibility of shell and tube heat exchanger, okay. And the methods employed to reduce thermal stresses okay.

So those methods are also available to prevent leakages and to provide ease of cleaning and to contain pressure and to contain operating pressures as well as temperature to control corrosion to accommodate high asymmetric flow and so on. So you can see the number of factors are available in which shell and tube heat exchanger is very flexible to accommodate all these factors, right.

So we can have so we can understand the utility of shell and tube heat exchanger is very wide and why it is so, fine? So shell and tube heat exchangers are classified and constructed in accordance with the widely used TEMA standards, okay. So as far as this classification is concerned this we are considering based on TEMA standards.

And what is TEMA standards? It is Tubular Exchanger Manufacturers Association, okay.

That is the American Standard which we refer as the TEMA standard, okay. And different nomenclatures are given to different shell and tube heat exchanger and accordingly you can choose the right heat exchanger as per your choice. So though shell and tube heat exchangers are very wide as far as its construction is concerned, but here we will classify based on main factor and then you will find the derivative of each class or category okay.

So let us classify the shell and tube heat exchanger. The first one or very common is the fixed tube sheet shell and tube heat exchanger. Next we have U-tube shell and tube heat exchanger and then we have internal floating head heat exchanger and finally we have external floating head heat exchanger and you will find further derivatives of all these, okay. So let us discuss these.

So let us discuss these heat exchanger one by one. So let us start with fixed tube sheet heat exchanger, okay.

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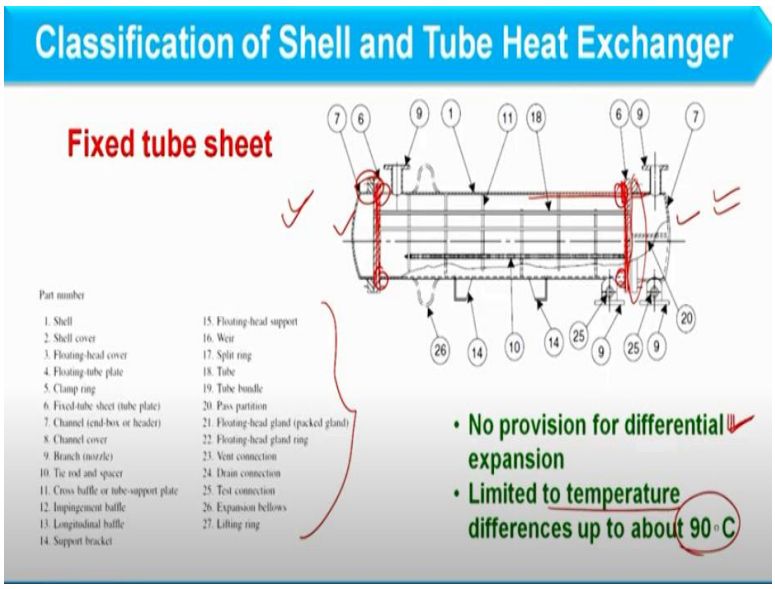


Now if you consider fixed tube sheet here we have the schematic with different numbers and these numbers are elaborated over here. I am not going into detail of these number because according to the number you can find the assembly in this figure very well. So the main point I am going to discuss about this, so main point we

are going to discuss about this heat exchanger where I am having fixed tube sheet, right.

So what is the meaning of fixed tube sheet? Fixed tube sheet means or first of all let me ask you what is the purpose of tube sheet? The purpose of tube sheet is it separates the liquid which is flowing in tube side and which is flowing in shell side, fine? So secondly the purpose of tube sheet is to hold the tubes, okay. So these are two purposes of tube sheet.

And if I am considering that tube sheet are fixed, it means it is permanently attached to the shell, okay. For cleaning purpose and etc., we cannot de-assemble it okay. So as far as flexibility is concerned that is very less in fixed tube sheet heat exchanger, okay. So if you consider this schematic, here I am having this is so here I am having this as a fixed tube sheet okay.

This as a fixed tube sheet where tubes are inserted and it is attached with this cover, okay with this cover and with this cover through this joint, okay. So this is basically the permanent joint and for cleaning purposes what we can do we can simply remove from here okay, remove from here and then we can clean it. So if I am saying that it can be removed, so how it is fixed, okay.

It is fixed in such a manner if you consider this is the shell right, this is the shell and this is the tube, fine. So here I am having permanent joint, permanent joint between shell and tube sheet, okay. So if I am saying fixed tube sheet the meaning is this, it is fixed with the shell. However cover can be removed, okay.

So once it is fixed with the shell, it means the tube bundle which includes the tube sheet, number of tubes, baffle rods etc., that you cannot remove from shell, right. It is fixed, permanently fixed with the shell. So what is the main point over here to consider? The main point is if I am fixing this heat exchanger from two end right, then what will happen?

If the fluid is moving in the tube side or in shell side if its temperature is more then what will happen? Because when I am dealing with high temperature right, if I am

dealing with high temperature, in metal sheet there is thermal expansion. And if I am dealing with cold temperature or very less temperature, it means thermal contraction will be there, okay. So that thermal contraction and expansion will occur in tubes only.

And if I am fixing the tubes and if I am fixing the tube sheets from two end and if thermal expansion will be there then what will happen? There will be bend in the tubes okay, tubes will bend okay because it cannot have the option to accommodate the thermal expansion and contraction, okay. So what is the limitation of fixed tube sheet shell and tube heat exchanger is it cannot used for high temperature fluids, fine?

It can be used for low temperature but cannot use for high temperature. Low temperature means it should not be very less also okay because contraction will be there, right. So the limitation of fixed tube sheet is there is no provision for differential expansion which we also called as thermal expansion okay, as well as thermal contraction also.

Therefore, the limitation of temperature which we can accommodate in fixed tube sheet should not exceed 90 degrees Celsius, okay. So that is the limitation. If you have fluid less than 90 degrees Celsius you should go for fixed tube sheet, okay. Now if I ask you what is the advantage of this, because obviously there must be some advantage so it is being used in industries.

The advantage is, it is very cheap in comparison to other shell and tube heat exchanger which we are going to discuss in subsequent slides. So you see advantage is in terms of cost, disadvantage is in terms of utility, right. So this limitation of fixed tube sheet can be accommodated or can be addressed in next shell and tube heat exchanger which we consider as U-tube heat exchanger, okay. This is the U-Tube heat exchanger.

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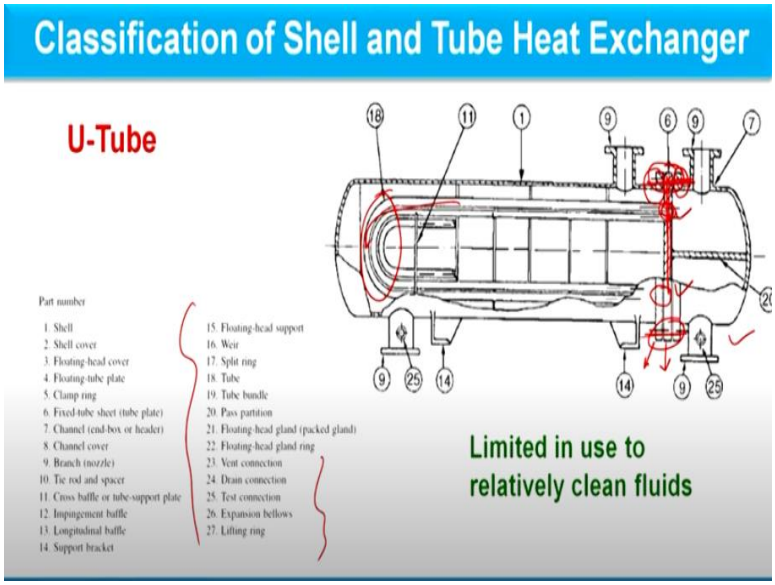


Again I am saying that I am not going to detail of these number that you can consider while referring to this figure and this figure as well as these details of different parts I have taken from volume six book, I have taken from volume six book, so you can refer that book, okay. Now if I consider U-Tube shell and tube heat exchanger, this is basically the U-Tube, right.

So U-Tube if I consider it is nothing but like hairpin, fine? So as far as its utility is concerned, can I use high temperature fluids in this? To understand that, let us discuss its geometry. So if you focus on this, here we have, if you consider this particular connection or this particular connection, then what will happen? Here this is the tube sheet right? This is the connection of cover.

And this is the connection of shell, fine. So if I open this, if I open this joint I can remove cover, I can remove this shell and I can take this bundle out, okay. So in this case bundle can directly be taken out from the shell for cleaning or maintenance purpose which is not possible in fixed tube sheet because there is a permanent joint between shell and tube sheet, right.

So what will happen in U-Tube? Because it is of U shape, okay no tube sheet is required at this side, okay. You see no tube sheet is required at this site. Only single tube sheet is required where one U-Tube is entered twice into tube sheet, one at this location, one at this location. But no tube sheet is available at this location. So what is the advantage over here?

Advantage is if you consider this space, here I am having sufficient space. If temperature increases and thermal expansion is taking place, if thermal expansion is taking place in tube side, so what will happen? This tube can move in this way or this tube can move in this way as well, okay. So this shell and tube heat exchanger accommodates thermal expansion and contraction very effectively because it does not have fixed tube sheet on another side.

Another side it has a U-Tube, which has the flexibility to move backward and forward, okay. However, no movement is required on fixed tube sheet side, okay. So the flexibility is it can be used for high temperature fluid, okay. Now what is the limitation? The limitation is because of this bend what will happen, if fluid is moving inside this it has more chance to scale formation in this bend, okay.

It has more chance to make scale in this bend and therefore, cleaning of this bend is very difficult because complete 180 degree bending is there okay. So whatever mechanical way or chemical way it is very difficult to clean. Therefore, the limitation of U-Tube heat exchangers are we should use clean fluids in U-Tube heat exchanger, okay.

However, clean fluid will also form the scale but that is very less in comparison to normal fluid, okay. So limitation is we should use clean fluid and advantage is we can use high temperature fluid because here thermal expansion and contraction can be addressed, okay.

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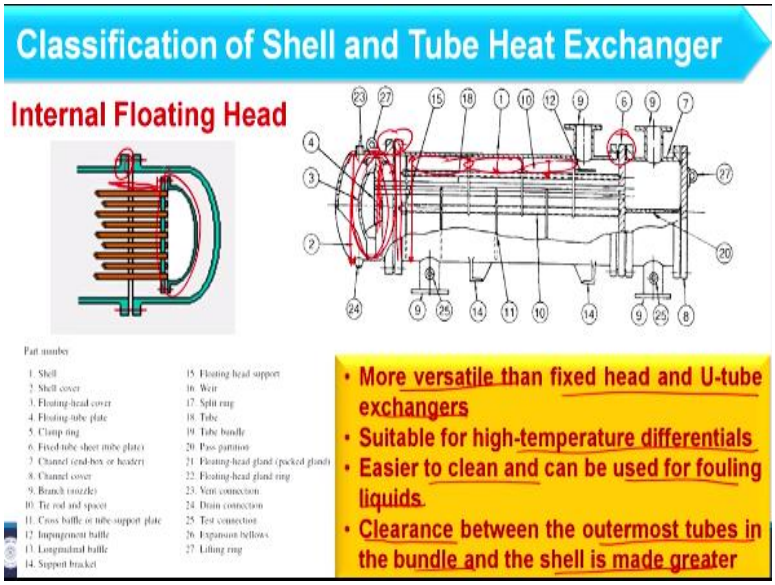


Now the problem is with high fouling fluids, what we have to do with that? To address that we have another heat exchanger that we consider as internal floating heat exchanger, fine? So if you focus on this heat exchanger again the same assembly as we have discussed in U-Tube, so bundle can be taken out no problem.

Now what will happen now what will happen at end side if you see here I am having this tube sheet, right and this tube sheet as well, okay where it is attached with the cover. Now what will happen? This tube sheet corresponds to the tubes, which are inserted in this, fine? And if you consider this tube sheet it means it is basically providing this much area for thermal contraction and expansion, okay.

So this complete tube sheet can move in this direction or can move in this direction depending upon the temperature it accommodates, okay. So what is happening over here? The complete tube sheet okay, the complete tube sheet of the tubes are lying within the shell diameter. If I consider this, this is the shell diameter and the same diameter you can find over here also.

I hope it is clear, okay. So you see this is basically the shell diameter and the same diameter is lying over here, okay. So complete tube sheet is lying within the shell, fine? So it is called as internal floating head because this section is floating and this is floating inside the shell diameter, okay. I am not saying inside the shell, but inside the shell diameter but obviously it will move in covered side, okay.

So if it is not moving inside the shell diameter, it is moving in covered side. So what is the problem? The problem is because complete tube sheet is within the shell diameter. The shell diameter in this case is very large in comparison to fixed tube sheet or U-Tube shell and tube heat exchanger, right. So the main problem lies over here, you see here.

So here I am having the clearance and this clearance is very large in internal floating head heat exchanger because here we have to install the complete heat exchanger within the shell diameter, fine? However, it has the flexibility also, okay. As you can see this is completely lying within the shell diameter.

This from this image it is more clear to you, right. Now it has some flexibility. It is more versatile than fixed tube sheet and U-Tube exchanger, that you can understand. Suitable for high temperature differentials because we have thermal expansion and contraction feasibility. Ease of cleaning and can be used for fouling liquids also because here straight pipes are there.

You can remove complete bundle out and then because of that straight pipe cleaning is very easy, okay in this type of heat exchangers. So we can consider more and more fouling tendency fluids in this in comparison to U-Tube and therefore it addresses the limitation of fixed tube sheet as well as U-Tube, okay.

And disadvantage is it has more clearance between outermost tube in the bundle and shell diameter because that gap is very large because of complete tube sheet is falling within the shell diameter, right. So the problem occurs over here is the clearance. This problem can be addressed, this problem can be addressed if I completely place this section over here, okay. It means that shell should start from here not here, right.

So if shell will start from here, what we can consider that this section is outside the shell diameter, okay. Outside the shell diameter meter means outside the cover which is equal to the shell diameter, right.

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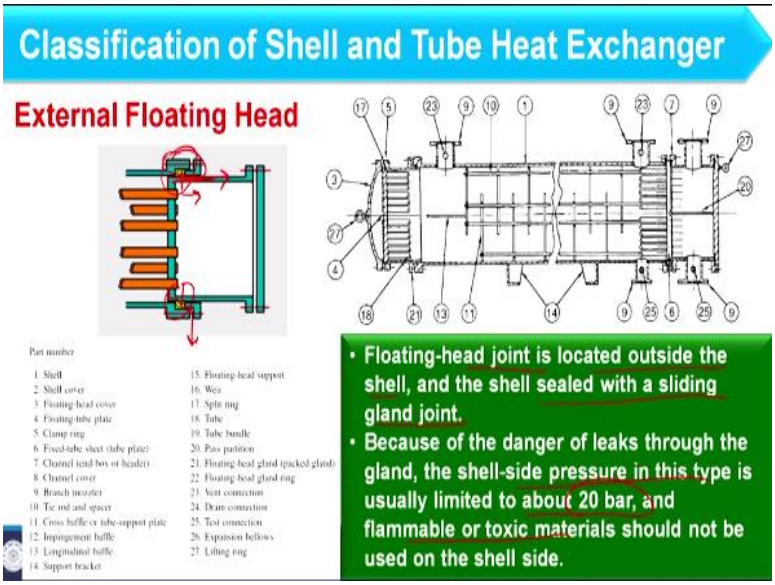


So that we consider as external floating head heat exchanger as you can find over here. So you see this is basically the external floating head. Here I am having the shell and this is the connection which can be removed. Now the point is I am having this assembly, right. And if I consider this tube sheet it can be moved forward or backward very easily because it is sliding over here. It is sliding over here, okay.

So here I am putting one sealing and the heat exchanger and the complete bundle can have differential and complete bundle can have thermal differential accommodation, right. It can be expanded or it can be contracted depending upon the temperature. Now what is the problem that if I consider the movement like this okay and this section will slide over here, right.

Now if this section moves in this way, then what will happen if this section comes over here, okay. If this section comes over here, then fluid can move or get out from this okay. So the limitation is though external floating head heat exchanger reduces the clearance significantly, it can leak the liquid. So leakages is the so leakage is the problem in this type of exchangers, okay.

So if I am using toxic fluid, we should not use that fluid in shell side. However, that we can use in tube side, no problem okay. So as far as floating head heat exchangers are concerned, it is basically external floating head and here floating head joint is located outside the shell and shell sealed with a sliding gland joint as you can see yellow section over here, okay.

And because of the danger of leaks through the gland, the shell side pressure drop in this type is usually limited up to 20 bar and we should not use flammable or toxic material. So you can see as far as flexibility is concerned internal floating head heat exchanger is most flexible. It can accommodate high temperature, it can accommodate fouling tendency fluid, it can accommodate toxic fluid, but low leakage etc., will occur.

But the only problem is the clearance. So the cost of shell in internal floating head is higher. So that you can address with external floating head while putting toxic fluid in tube side, right.

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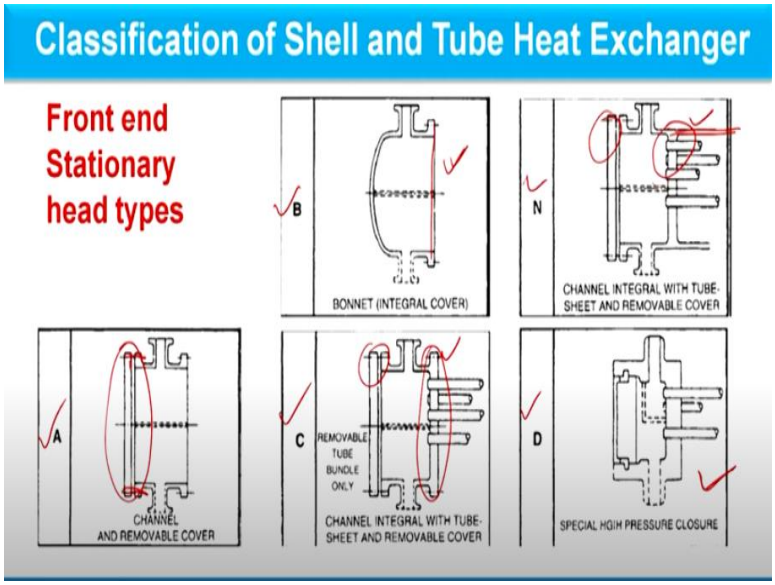


So here I am considering some stationary heads of front and rear side. So you can consider front head. So here we have channel and removable cover. So here you can simply remove this cover which is associated, which we can consider as the cover of flange okay because it is attached through this using a flange, okay. Here I am having bonnet type of structure.

Here I am having channel integral with tube sheet and removable cover. So here we should we do not have any tube sheet but here it is connected or integrated with the tube sheet and cover can be removed. And here also we can have integrated tube sheet with cover, integrated tube sheet with the channel and here we can remove the cover.

But the difference between this and this is here we have the tube sheet and here we have direct shell, right. And this is used very special and this is used for very high pressure fluids and high pressure closure we can consider like this. So if you consider this A, B, C and D what these are? These are basically TEMA standards. If you see TEMA C, TEMA C will remain only channel integral with tube sheet and removable cover. You cannot name C to any other combination, right.

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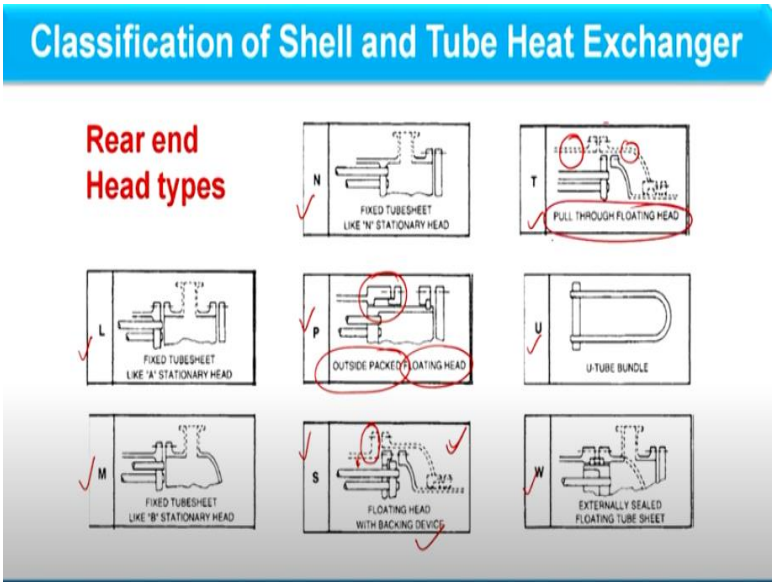


In the similar line I am having a rear end also, okay. So you can see here I am having L, M, N, P, S, T, U, W all these nomenclatures as per TEMA standard. So let us, here if you see this floating head okay, floating head be also called as outside pack because this is outside the shell, right. So here this sealing whatever we have discussed in external floating head that is available over here.

And this is another type of head where it is internal floating head but we can remove the clearance by putting less diameter shell, okay. Cover diameter is large, but shell diameter is small. So this is we call as a split ring okay. So floating head with backing device. So this we consider as split ring floating head heat exchanger, okay. And this internal floating head, if you consider diameter over here and here is equal, okay.

So this we call as pull through floating head because it is completely taking out okay and it can move in the shell as well. So this is basically pull through shell and tube heat exchanger. U-Tube you understand very well and here we have externally sealed floating tube sheet, okay.

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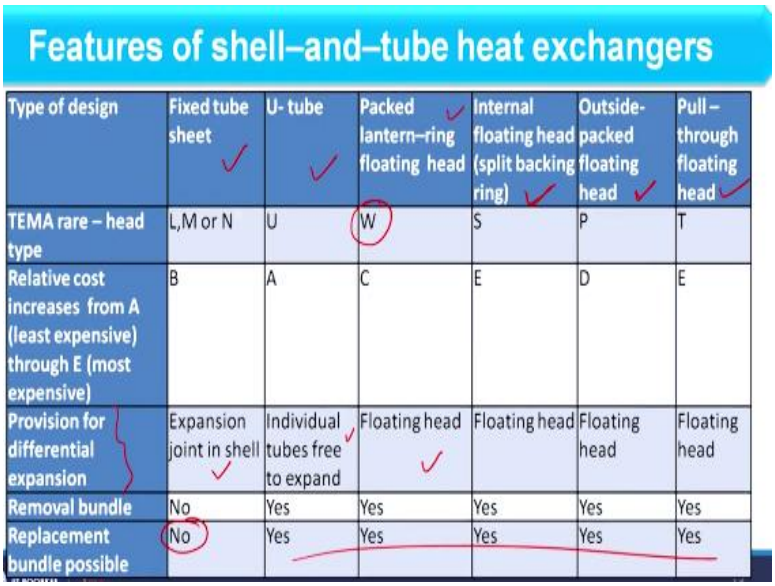

Features of shell–and–tube heat exchangers

| Type of design | Fixed tube sheet | U- tube | Packed lantern–ring floating head | Internal floating head (split backing ring) | Outside-packed floating head | Pull – through floating head |
|---|---|---|---|---|---|---|
| TEMA rare – head type | L,M or N | U | W | S | P | T |
| Relative cost increases from A (least expensive) through E (most expensive) | B | A | C | E | D | E |
| Provision for differential expansion | Expansion joint in shell | Individual tubes free to expand | Floating head | Floating head | Floating head | Floating head |
| Removal bundle | No | Yes | Yes | Yes | Yes | Yes |
| Replacement bundle possible | No | Yes | Yes | Yes | Yes | Yes |

So these are some rear end and here we have some features of shell and tube heat exchangers depending upon the type of exchanger like fixed tube sheet, U-Tube, packed lantern-ring floating head that is the TEMA W and if you see this is basically TEMA W, okay. And here we have internal floating head. And here we have internal floating head with backing strip.

And then outside packed floating head and then this is basically internal floating head that is pull through floating head. So here I am having different conditions like provisional for differential expansion, provisional of differential expansion so we can have expansion joint in shell, okay. So that is basically the fixed joint. And we have internal tubes free to expand.

Then floating head is there and similarly we can consider other shell and tube exchanger also. Replaceable bundle possible. In fixed tube sheet it is not possible. In other case it is possible.

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## Features of shell–and–tube heat exchangers

| Type of design | Fixed tube sheet | U- tube | Packed lantern–ring floating head | Internal floating head (split backing ring) | Outside-packed floating head | Pull – through floating head |
|---|---|---|---|---|---|---|
| Individual tubes replaceable | Yes | Only those in outside row | Yes | Yes | Yes | Yes |
| Tube cleaning by chemicals inside and outside | Yes | Yes | Yes | Yes | Yes | Yes |
| Interior tube cleaning mechanically | Yes | Special tools required | Yes | Yes | Yes | Yes |
| Exterior tube cleaning mechanically: | | | | | | |
| Triangular pitch | No | No | No | No | No | No |
| Square pitch | No | Yes | Yes | Yes | Yes | Yes |

In the similar line we can consider tube cleaning by chemical inside and outside. Everywhere it is yes, okay. Considering mechanical cleaning we can do that in U-Tube also but special tools are required. However, it can be done in other exchangers, okay.

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## Features of shell–and–tube heat exchangers

| Type of design | Fixed tube sheet | U- tube | Packed lantern–ring floating head | Internal floating head (split backing ring) | Outside-packed floating head | Pull – through floating head |
|---|---|---|---|---|---|---|
| Hydraulic – jet cleaning: | | | | | | |
| Tube interior | Yes | Special tools required | Yes | Yes | Yes | Yes |
| Tube exterior | No | Yes | Yes | Yes | Yes | Yes |
| Number of tubes passes | No practical limitations | Any even number possible | Limited to one or two passes | No practical limitations | No practical limitations | No practical limitations |
| Internal gaskets eliminated | Yes | Yes | Yes | No | Yes | No |

And if you see here we have the number of tube passes, so no practical limitation. You can accommodate any pass in fixed tube sheet, any even number possible okay in U-Tube because each tube will give at least two passes, right. So even number is possible. Even this number of passes of tube that we will discuss in detail in tubes, okay. So there we can consider that whether it is even or odd, fine?

So further if I consider packed-lantern ring floating head that is TEMA W we have limited to one or two passes only because of the design, complicated design. No practical in spluttering heat exchanger and external floating head as well as internal floating head, okay. So here you see we have different points based on which we can compare the shell and tube heat exchangers of different types.

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And here we have the references. You can go through these references for details.

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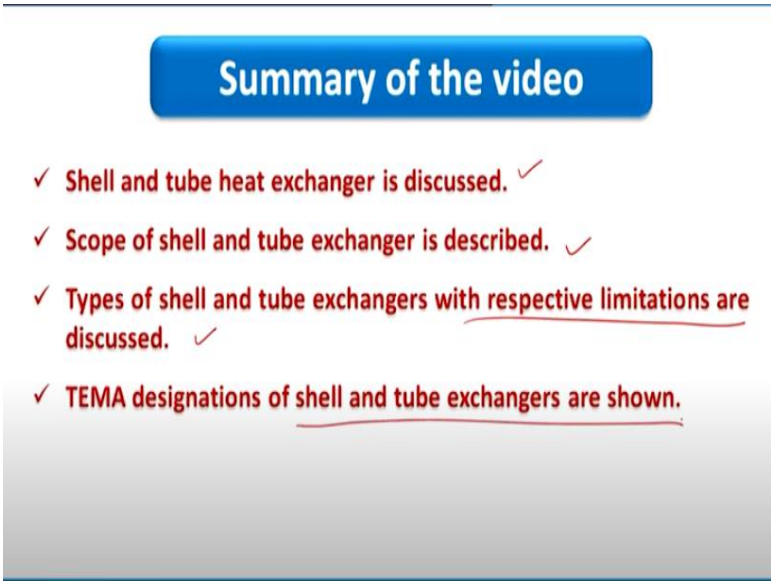


And here I am going to summarize this lecture which, and here I am going to summarize this lecture as in this lecture shell and tube heat exchanger is discussed. Scope of shell and tube heat exchanger is described in detail. Types of shell and tube

heat exchanger with respective limitations are discussed. And then we have discussed TEMA designation of shell and tube heat exchangers.

And we have also seen the comparison of different shell and tube heat exchanger depending upon different factors. So that is all for now. Thank you.