Principles and Practices of Process Equipment and Plant Design
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Module - 03
Lecture - 48
Shell and Tube Heat Exchanger- Design

Hello everybody. We will be continuing today with our discussions on the design of Shell and Tube Heat Exchangers. So, without wasting any time I will directly go to the process, the problem was already given to you. It was just an extension of the problem which was given for the double pipe exchanger. So, the same problem with a higher flow rate has been given so that you can start designing a shell and tube heat exchanger with it.

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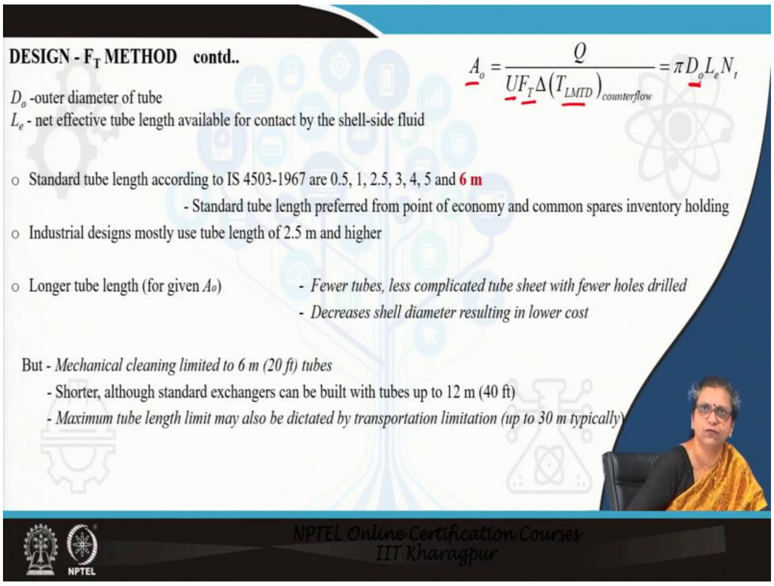

So, in the last class what we had done is, we had discussed how to assume the U, how to find out F T, calculate delta T LMTD from there we can find out the total area of heat transfer. Now, once we have decided on the total area of heat transfer we make some certain assumptions and certain calculations. First thing what we do is, we assume the outside diameter of the tube through which the heat transfer occurs.

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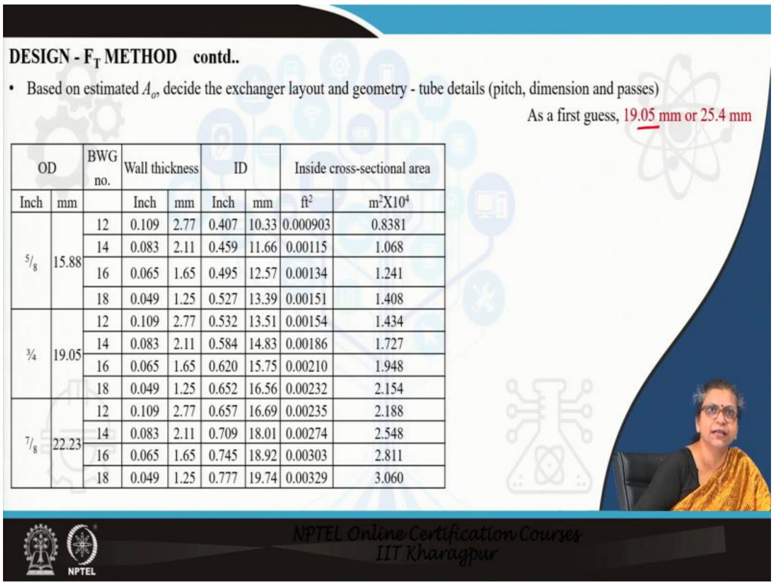

This was already told to you in the last class that as a first case we usually take either 19.05 millimeters or it means we either take a three fourth inch or a 1 inch pipe. Now, the thing is that, why do not we generally prefer to go below three fourth inch? Although you will find that from the codes the data on 5/8 inch is also available. The primary reason is that it is difficult to mechanically clean tubes smaller than three fourth inch.

So, therefore, unless otherwise specified it is or rather we can go for chemical cleaning or certain other things are specified, for example we will need a very high velocity or something. We would preferably not go below 3 4th inch and we would like to keep the pipe the other tube diameters around 1 inch. So, this is to start with and then maybe while we go along with the design it can happen that will have to modify this particular thing.

So, just remember it is quite evident that we would be preferring smaller tube just because it ensures a higher velocity which gives you a higher heat transfer coefficient, but at the same time it incurs a higher pressure drop. But when you have a higher heat transfer coefficient at a higher velocity quite naturally if you have smaller tubes then it leads to a more compact heat exchanger also.

And we prefer the larger diameter tubes primarily from the point of cleaning, ease of cleaning because that provision has to be kept in mind. And slightly higher diameter tubes they are more rugged also. So, therefore, and definitely the pressure drop also will be less so with these things we decide on the tube diameter.

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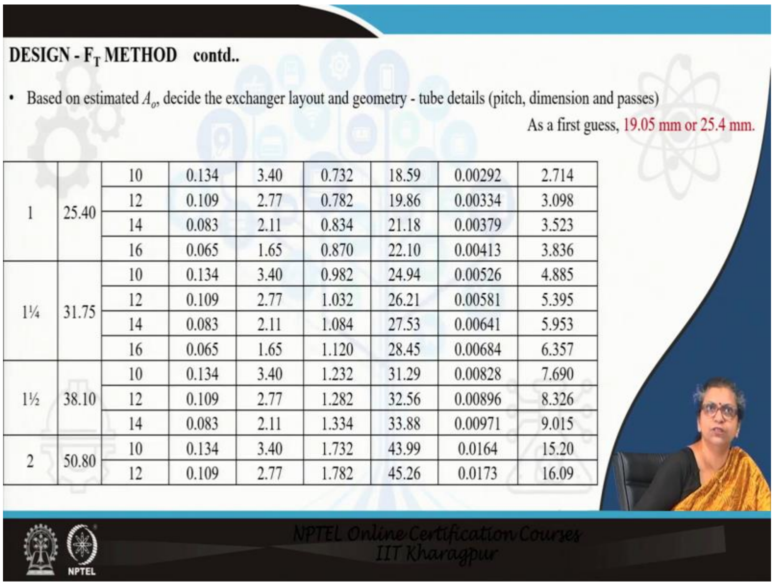

1	25.40	10	0.134	3.40	0.732	18.59	0.00292	2.714
		12	0.109	2.77	0.782	19.86	0.00334	3.098
		14	0.083	2.11	0.834	21.18	0.00379	3.523
		16	0.065	1.65	0.870	22.10	0.00413	3.836
1¼	31.75	10	0.134	3.40	0.982	24.94	0.00526	4.885
		12	0.109	2.77	1.032	26.21	0.00581	5.395
		14	0.083	2.11	1.084	27.53	0.00641	5.953
		16	0.065	1.65	1.120	28.45	0.00684	6.357
1½	38.10	10	0.134	3.40	1.232	31.29	0.00828	7.690
		12	0.109	2.77	1.282	32.56	0.00896	8.326
		14	0.083	2.11	1.334	33.88	0.00971	9.015
2	50.80	10	0.134	3.40	1.732	43.99	0.0164	15.20
		12	0.109	2.77	1.782	45.26	0.0173	16.09

In the last class I had shown you these two tables where for each particular OD the other details are available which you can use and you can go ahead. Once that is done next is the length of the tube. Now, regarding the length of the tube I had already mentioned that the standard tube lengths which are there according to codes, we would always like to prefer standard tube lengths.

Simply because there then it is very easy to get the spares and it is also very easy to means the delivery time a faster delivery time is also ensured etcetera. So, therefore, the standard lengths have been mentioned and I told you that generally we would not like to have tube diameters lower than 2.5 meters.

There are certain things that it is important for you to remember that, if the shell diameter to the length of the heat exchanger is less than 3 then in that case there is every chance that the entry and exit losses they become significant compared to the loss which is incurred during the straight flow through the pipe.

As a result, we would be encountering quite a high amount of pressure drop which we do not want. Again at the same time we would not like to go for tubes larger than say 12, 30 meters or so for two reasons, one is definitely a transportation is the problem the other thing you have to remember that anyhow the heat exchanger occupies a good amount of float space.

So, and also you need to keep some other space from where the tube can be taken out and it can be introduced into the shell. So, therefore, some additional space also has to be kept for that. So, keeping these things in mind we are usually we adopt 6 meters or 12 meters of tubes. For the present design what we would prefer is, we would prefer we will first start with 6 meters of tubes go for multiple passes then if required we will think of something else.

And the other thing is if you take a longer tube which is also important that naturally then lesser number of tubes will be required then lesser number of tubes will be required lesser number of holes have to be; have to be drilled in that tube sheet. So, therefore, it becomes the design becomes less complicated and also you know that when fewer tubes are required so, naturally in that case it goes for a lower cost also.

So, anyhow so based on this more or less we are going to adopt the tube length as usually I will start with 6 meters length. Now, this was also discussed in the last class, will this 6 millimeters be available for heat transfer or not. Because it is very evident to you that if you look at the tube then in that case you are going to see that there is some amount of tube which will be within this particular tube sheet.

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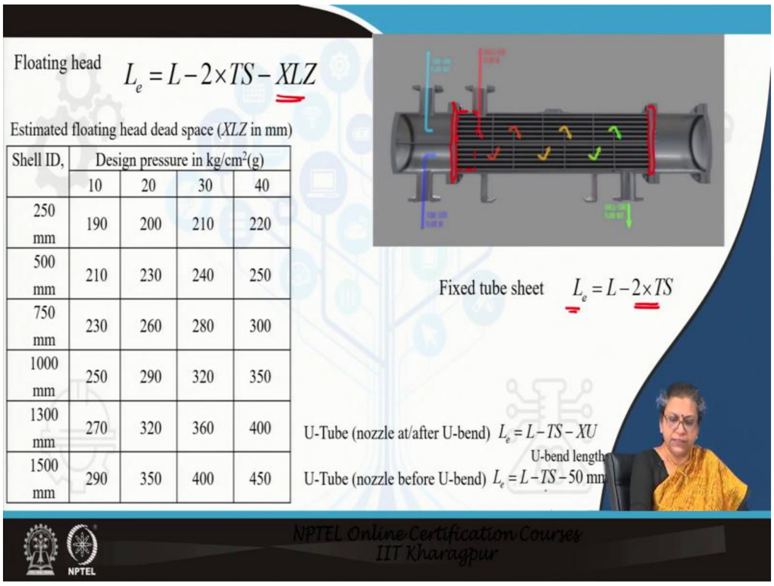

So, this particular tube part of the tube this will not be available for heat transfer. So, naturally if you have a fixed tube sheet we have to subtract 2 into the tube sheet thickness from the total length of the tube to, in order to get the effective length of the tube which is actually available for heat transfer.

Now, when we have a floating head what happens definitely these 2 tube sheets are there, along with that there is a dead space which is the basically this portion of the space which is beyond the nozzle of the shell side fluid because, this part is also not available for heat exchange and.

So, therefore, we have to subtract an additional portion of the length also. Now, the question is will we not have to subtract this for the case of a fixed tube sheet? Usually you will find that the nozzle is placed as close as possible to the tube sheet so that the dead space is minimized.

But, for the floating head this part is there again from the codes based on the shell ID and the design pressure the dimensions of XLZ is there which you can consider and you can go ahead with this. Similar, codes or similar specifications in the codes are also available for your U tubes as well depending upon the placement of the nozzle before the U tube or after the U tube.

If the nozzle is placed before the U tube the entire U bend is available and in that case more or less we just subtract the thickness of the tube sheet, and if it is after the nozzle we have to subtract some particular length which is also available in the codes well. So, now next is, what is the tube sheet thickness that, that you have to subtract here and to find out the effective length? So, what is this particular tube sheet thickness?

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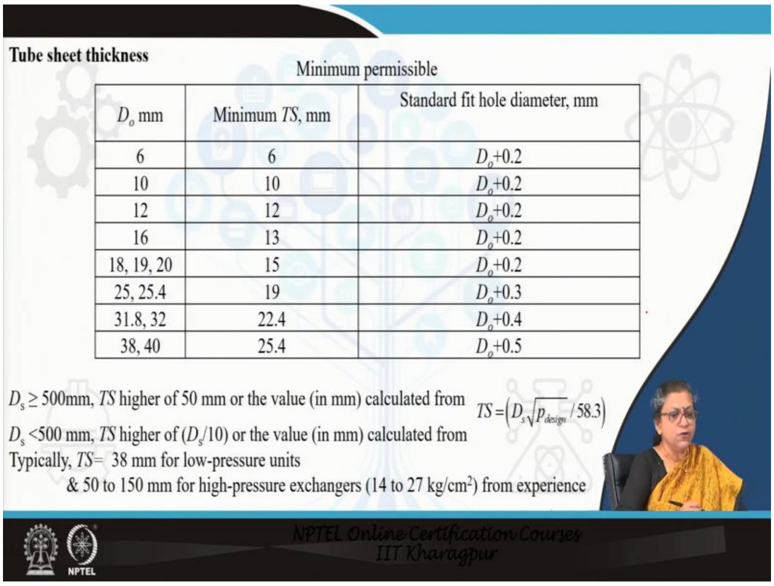

So, therefore, again the codes have come to a rescue and more or less the minimum permissible tube sheet thickness is specified as is given in this particular table. So, you need to respect this particular minimum tube sheet thickness you have to ensure that the tube sheet thickness that you have considered is more than the minimum that you have specified.

Generally, we find that for the tubes of diameters 25 millimeters or less the tube sheet thickness is usually not lower than the outer diameter of the tubes. So, therefore, TS is not less than D o, for D o equal to or less than 25 millimeters that is usually. There are certain other typical things that you can you can do, whenever you have found out the tube sheet thickness definitely need to check that it is above the minimum.

And for deciding the tube sheet thickness usually you can either take its the thumb rule that you can either take 50 millimeters or you can calculate it from this particular formula whichever is higher you can take it you can adopt that particular value when the shell diameter is greater than or equal to 500 millimeters.

For shell diameters less than 500 millimeters TS is again the higher of D s by 10 or the value calculated in millimeters from this particular formula. So, you can take it typically to start with you can assume, TS equals to 35 millimeters for low pressure units, 50 and to 150 millimeters for high pressure units the heat exchanger which you are supposed to design will be a low pressure unit. So, therefore, you can start with 38 millimeters and then find out the effective tube length.

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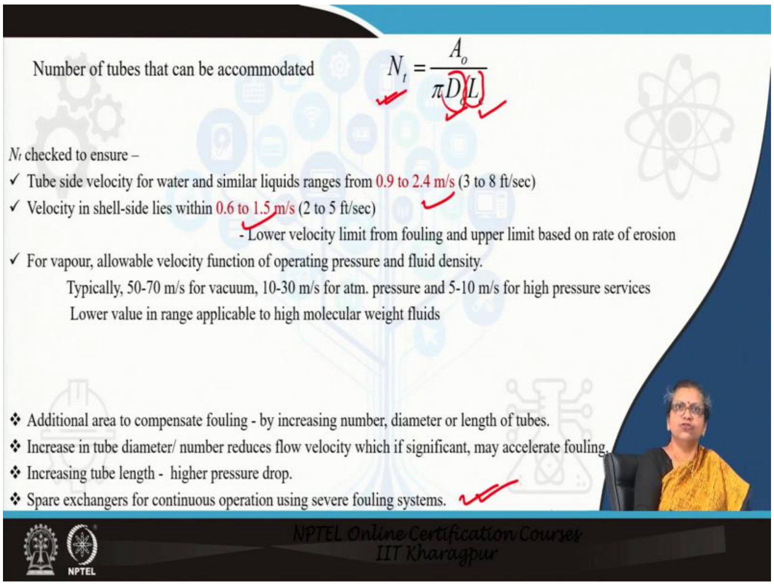

Once the effective tube length has been found out the D o has been assumed so now, you can go ahead to find out the number of tubes. Now, one thing is for there the number of tubes on what does it depend or rather what does it influence the fluid flow rate and the available pressure drop right. So, these are the two things which have to be respected when you are designing or you are deciding on the number of tubes.

So, therefore, after you have decided the number of tubes you need to make some amount of checks depending upon the fluid that you are dealing with you just need to check or whether the tube side velocity and the shell side velocity they respect the or they lie within these particular limits or not. Where it is quite evident if the velocity is lower then there are chances of fouling, if the velocity is higher than the erosion rate of erosion or the erosion chances are more.

So, therefore, if you have water and similar liquids then the velocity in the tube side and shell side must confirmed to these particular specifications. If you have having vapour quite naturally the vapour velocity will be a function of operating pressure and fluid density and these particular ranges they are provided and these need to be respected in your case.

One more thing also you need to remember if you are using too many tubes then in that case too many holes have to be drilled in the tube sheet and under that case it the tube sheet becomes weaker. So, this is also a consideration that you need to keep in mind. So, if you find that after you have calculated the N t does not respect these things then there are certain things that you can do right.

And often what you do is, you need to provide additional area to compensate for fouling. How can you provide this additional area? You can either increase D o or you can increase L e or you can increase N t. When you increase D o what happens? Naturally, the velocity decreases the chances of fouling increases you have to keep this in mind. Same thing is true for when you increase the number of the tubes. When you increase the tube length the pressure drop considerations have to be kept in mind.

When you find that in order to comply to these velocity constraints it is not possible for you either to change any of these D o, L e, N t from pressure drop fouling etcetera etcetera, considerations then it can always happen that for severe fouling cases you may have; you may have to keep a spare exchanger in space for to ensure continuous operation of the system that can also happen.

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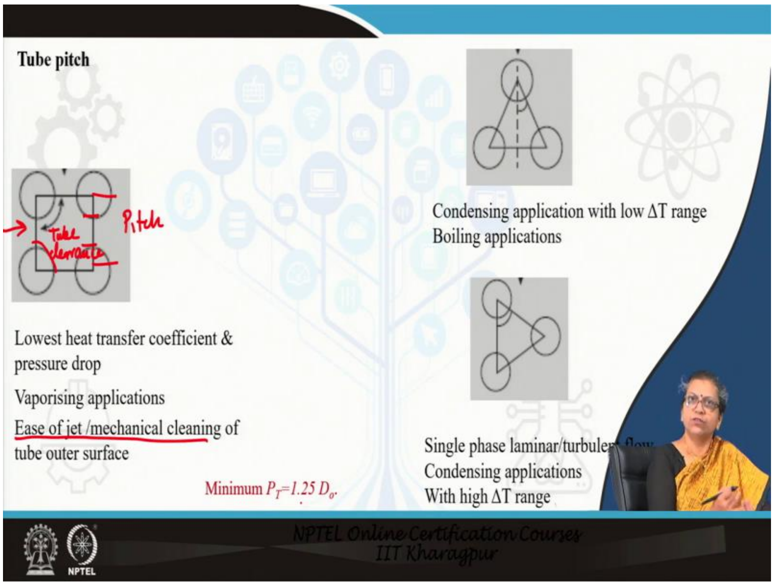

Well. So, therefore what are the things we have decided on the number of tubes tube length and the tube diameter. Now, we have to arrange the tubes inside the shell and accordingly we have to drill the holes in the tube sheet and arrange the tubes. This has already been discussed to you that the tube pitch it can either be square or it can be a rotated square it is just a rotated square or a triangle equilateral triangular pitch or maybe a rotated equilateral triangular.

These pitches, as has already been told to you, are defined in terms of the included angle with respect to the flow direction of the shell side fluid. In short the advantages disadvantages have been told to you, in short the square pitch definitely it guarantees the lowest heat transfer coefficient and the lowest pressure drop. And the main important advantage of this is the ease of mechanical cleaning of the outer tube surface they are used for vaporizing applications.

Now, when cleaning is not a factor for example, when we are using fixed tube sheets under that conditions definitely we would be preferring an equilateral triangular pitch because an equilateral triangular pitch two things. Firstly, it ensures greater number of tubes within the same particular area and the other thing is that it guarantees naturally it guarantees a heat transfer coefficient of about 25 percent higher provided all other factors remain the same.

So, naturally when we are going for maybe you will be opting for a fixed tube sheet under that condition, you can opt for a triangular pitch if pressure drop constraints are respected. And when we go for a triangular and a rotated triangular pitch everything is mentioned here so accordingly you can decide the pitch.

Now, after you have decided the pitch again generally thus the pitch is actually the center to center distance this is the pitch remember. And this particular part the distance between the tubes this is known as the tube clearance. Normally, the minimum pitch is 1.25 of the outside diameter this is the minimum. If suppose you have the tubes are much closer than this the tube sheet becomes weaker from that considerations the minimum has been decided.

So, what I would suggest is when you go for your design you can first adopt the minimum and see if you can accommodate all your tubes or not because when you go for a minimum naturally you are utilizing the minimum space quite natural shell diameter will be the minimum. So, it might come out to be more economic if its fine then you can proceed or else you may think of increasing the tube pitch.

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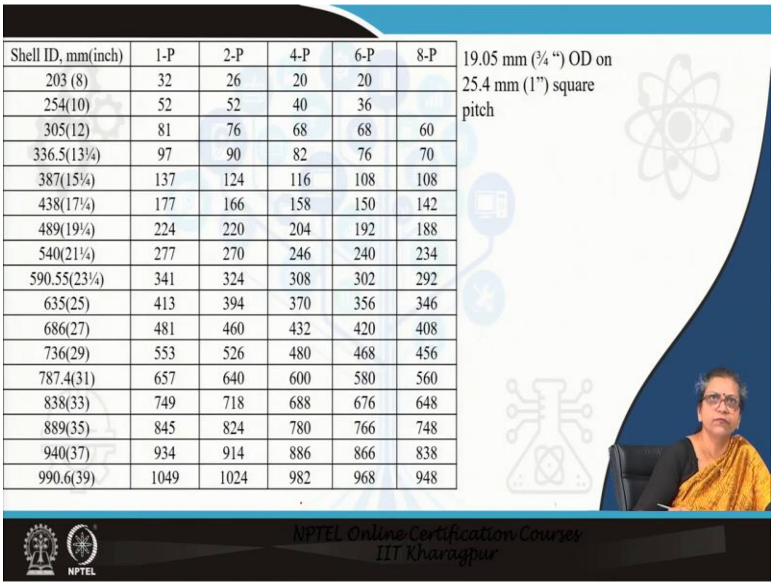

Shell ID, mm(inch)	1-P	2-P	4-P	6-P	8-P
203 (8)	32	26	20	20	
254(10)	52	52	40	36	
305(12)	81	76	68	68	60
336.5(13¼)	97	90	82	76	70
387(15¼)	137	124	116	108	108
438(17¼)	177	166	158	150	142
489(19¼)	224	220	204	192	188
540(21¼)	277	270	246	240	234
590.55(23¼)	341	324	308	302	292
635(25)	413	394	370	356	346
686(27)	481	460	432	420	408
736(29)	553	526	480	468	456
787.4(31)	657	640	600	580	560
838(33)	749	718	688	676	648
889(35)	845	824	780	766	748
940(37)	934	914	886	866	838
990.6(39)	1049	1024	982	968	948

Well, after everything has been decided then. See, normally you can adopt any pitch that you want ok if it is greater than 1.25, but again in this case it is advisable that you follow some particular codes. So, therefore, as per the codes and this table it has been taken from the book by Kern heat transfer by Kern.

The table in Kern is an FPS unit, we have converted it into the them in terms of millimeters. From here the shell diameter I will be discussing, once you know the shell diameter you know the total number of tubes then from there you can decide on the number of passes as well, right.

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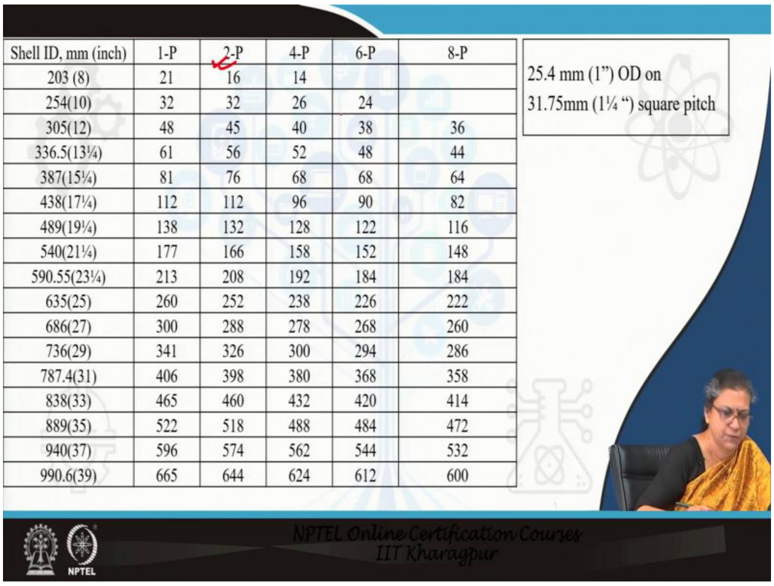

Shell ID, mm (inch)	1-P	2-P	4-P	6-P	8-P
203 (8)	21	16	14		
254(10)	32	32	26	24	
305(12)	48	45	40	38	36
336.5(13¼)	61	56	52	48	44
387(15¼)	81	76	68	68	64
438(17¼)	112	112	96	90	82
489(19¼)	138	132	128	122	116
540(21¼)	177	166	158	152	148
590.55(23¼)	213	208	192	184	184
635(25)	260	252	238	226	222
686(27)	300	288	278	268	260
736(29)	341	326	300	294	286
787.4(31)	406	398	380	368	358
838(33)	465	460	432	420	414
889(35)	522	518	488	484	472
940(37)	596	574	562	544	532
990.6(39)	665	644	624	612	600

Now, these particular this data it is available both for square pitch and for triangular pitch for different sizes of the outside diameter of the tube and the square pitch. And. so therefore, after you have selected the square or triangular pitch you have decided on the OD of the tube you can select your pitch. And then based on the pitch you refer to the correct table and to decide on the number of passes. Usually, we would prefer 2 passes if one pass does not suffice, normally we do not go beyond 4 or 6 passes if it is possible.

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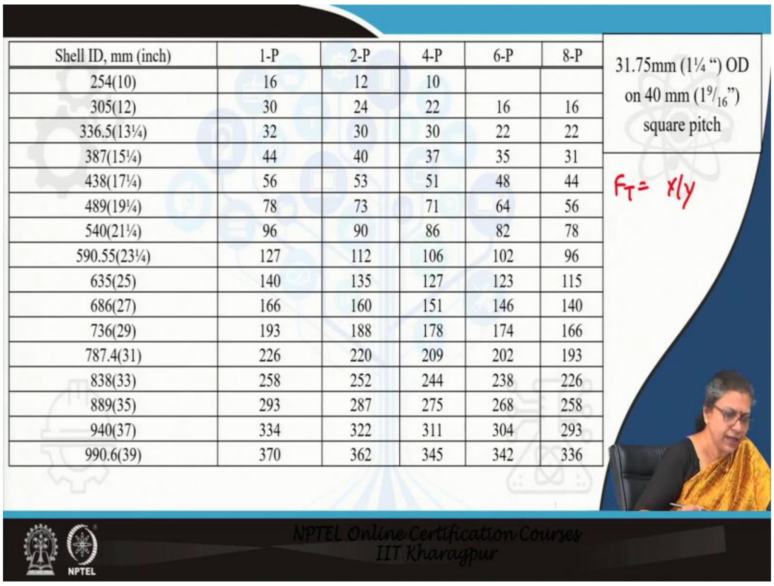

Shell ID, mm (inch)	1-P	2-P	4-P	6-P	8-P
254(10)	16	12	10		
305(12)	30	24	22	16	16
336.5(13¼)	32	30	30	22	22
387(15¼)	44	40	37	35	31
438(17¼)	56	53	51	48	44
489(19¼)	78	73	71	64	56
540(21¼)	96	90	86	82	78
590.55(23¼)	127	112	106	102	96
635(25)	140	135	127	123	115
686(27)	166	160	151	146	140
736(29)	193	188	178	174	166
787.4(31)	226	220	209	202	193
838(33)	258	252	244	238	226
889(35)	293	287	275	268	258
940(37)	334	322	311	304	293
990.6(39)	370	362	345	342	336

Note one thing all of these they are in terms of 1 shell pass and multiple tube passes right. So, therefore, you can use F T equals to X by Y, that particular formula and you can go ahead, I believe this should be sufficient if not then we will think of using more number of shell passes normally that is possibly that will not be required.

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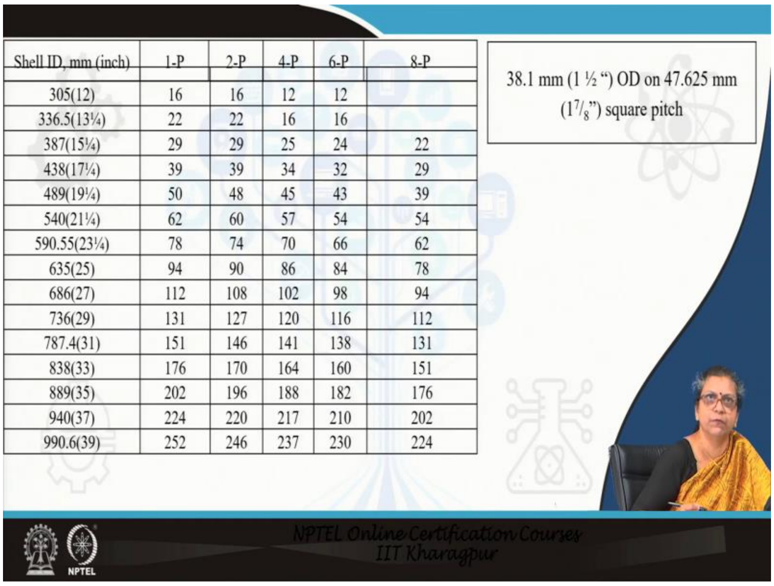

Shell ID, mm (inch)	1-P	2-P	4-P	6-P	8-P
305(12)	16	16	12	12	
336.5(13¼)	22	22	16	16	
387(15¼)	29	29	25	24	22
438(17¼)	39	39	34	32	29
489(19¼)	50	48	45	43	39
540(21¼)	62	60	57	54	54
590.55(23¼)	78	74	70	66	62
635(25)	94	90	86	84	78
686(27)	112	108	102	98	94
736(29)	131	127	120	116	112
787.4(31)	151	146	141	138	131
838(33)	176	170	164	160	151
889(35)	202	196	188	182	176
940(37)	224	220	217	210	202
990.6(39)	252	246	237	230	224

38.1 mm (1 ½ ") OD on 47.625 mm ($1^7/_8$") square pitch

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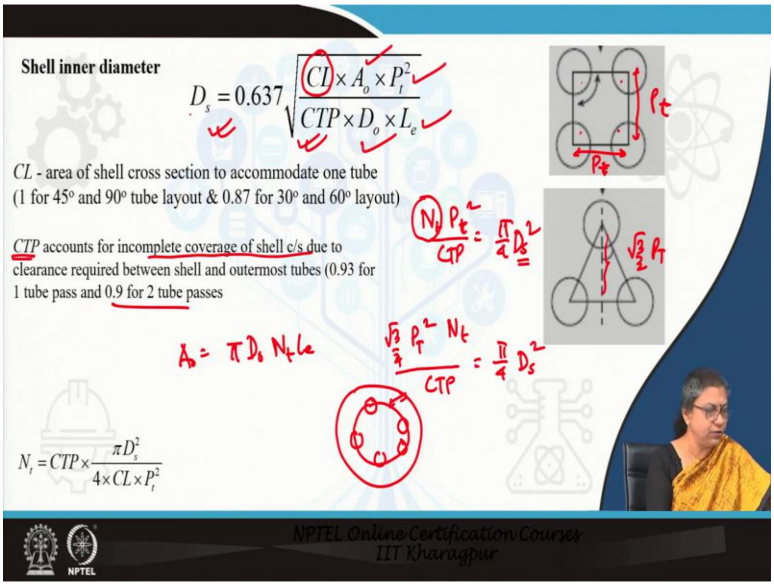

Well, after this the next thing is the shell inner diameter. Now, considering the shell inner diameter how are we going to find it out? Say, suppose for the square pitch for the square pitch, what do we find? That for this particular area this is P t this is P t.

So, therefore, what is this area? This area is P t square. I have I have denoted it with a small t. In this P t square how many holes have been accommodated? This P t square one fourth, one fourth, one fourth, one fourth so therefore one hole has been accommodated.

So, for one hole the cross section of the shell that is utilized is P t square provided we are going for a square pitch. So, for N t number of holes how what will be the cross sectional area of the shell? It should be N t into P t square provided it is a square pitch. If it is not a square pitch then in that case what do we find its going to be?

It is going to be in this particular case if this is P t then this is going to be sin 60 so, root 3 P T and so therefore, from there if you find its going to be root 3 by 2 P T square from half base root 3 by 4 I believe. From half base into height you are going to get this and that is going to accommodate your one particular tube.

So, therefore, here also this into N t gives you, but that it should give you the total shell cross section which will be required to accommodate N t number of tubes. Now, there is one thing do you think that inside the shell the tubes will be completely tight fitted it is not.

So, there has to be some clearance between say this is the shell and suppose this is the we say it is the ODL the outer tube diameter limit. So, therefore, there should be some distance so that the tube sheet can be pulled out and it can be introduced without doing any damage to the shell.

So, therefore, there has to be some particular clearance in this particular case. And naturally when you are having a single pass, then you need to ensure that there is sufficient clearance between the shell OD and the last or the outermost location of the tubes. If it is a double pass then we need to find we need to ensure that from both the partition as well as from the shell outside diameter there is sufficient clearance.

So, accordingly to take this into account one particular factor is considered which accounts for the incomplete coverage of the shell cross section due to the clearance, which is required between the shell and the outermost tubes. This clearance naturally the smaller amount of clearance has to be kept for 1 tube pass a slightly more number of clearance has to be kept for 2 tube passes.

If you have higher number of tube passes then the number the fraction of the clearance that has to be kept that has to be naturally increased. And so accordingly CTP decreases with the increase in number of passes, its 0.93 for 1 pass 0.9 for 2 tube passes right. So, therefore what do we do with this particular thing naturally we also include the CTP here also.

So, therefore, we divide it by CTP so that we can accommodate for the extra area which is required and then we compute the shell diameter. So, therefore, this whole thing this should be equal to pi by 4 into D s square right, here it should be this by CTP this should be equal to pi by 4 into D s square.

So, therefore, in this if you substitute N t from A 0 equals to pi D 0 N t L e, if you substitute this here and then if you find D s you will find that this is the formula where, in order to account for both the triangular as well as the square pitch we have denoted this particular fraction as CL, but CL naturally it is 1.

Since this is the correction factor to P t just to account for the difference in the cross sectional area of the shell in order to accommodate 1 tube for the square pitch and for the triangular pitch, right. So, therefore, this CL naturally this is equal to 1 for 45 and 90 degrees and this is equals to 0.87 which is root 3 by 2 for 30 and 60 degrees layout and.

So, accordingly you can find out the D s from here you find that you know A o you have decided P t you know L e you know D o, CTP you can very well find out generally if it is 2 pass its 0.9 so you can find out D s. Once you can find out D s then, if you see by here you know D s so accordingly you can proceed.

And with this you have decided you have decided the tube dimensions, you have decided the shell dimension, you have decided the tube arrangements, you have decided the number of tubes, you have also decided the length of the tubes or the you have decided the length of the heat exchanger.

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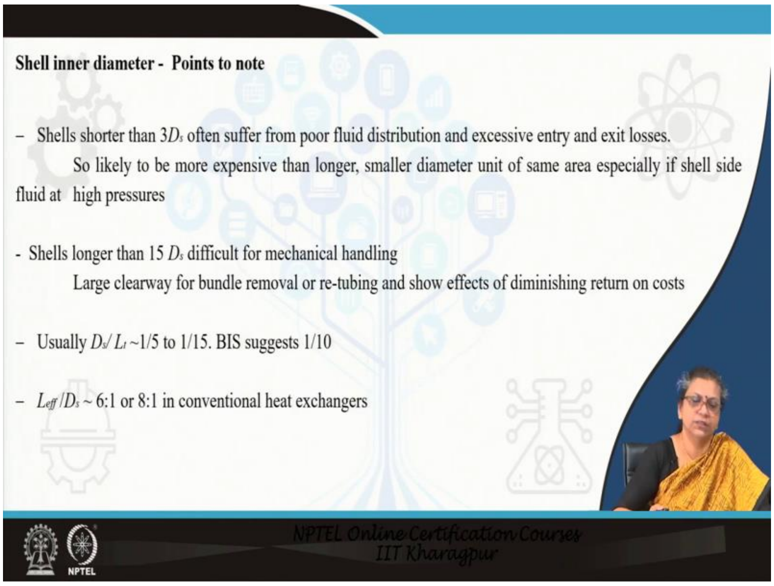

Just like I had I have already discussed these particular things that, shells shorter than when the length is shorter than 3 times the diameter quite naturally they suffer from poor fluid distribution. Longer than 15 times I have already said it is difficult for mechanical handling. So, normally we would like to respect this particular ratio.

So, once the shell diameter has been decided just check up whether this particular ratio is fine or not and we can also this is the conventional heat exchangers they generally maintain this particular ratio. So, therefore, these things have to be checked with time as you proceed with the design just to ensure that you are doing a proper design.

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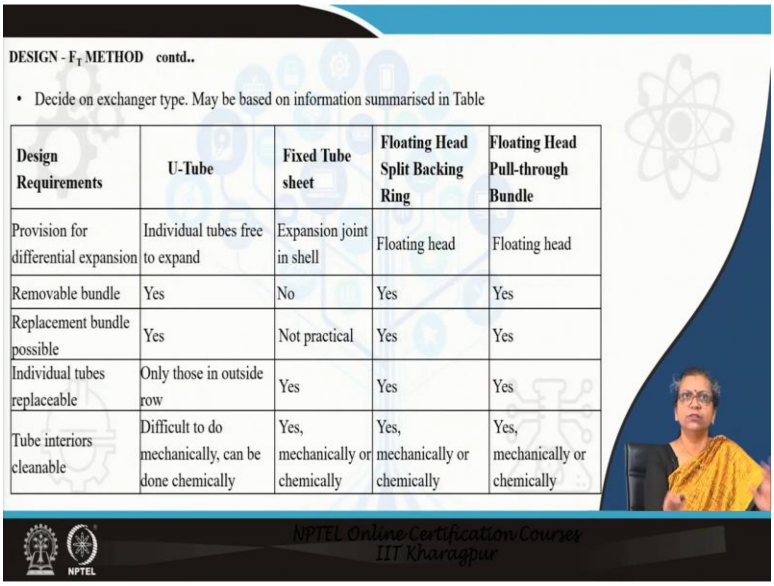

Design Requirements	U-Tube	Fixed Tube sheet	Floating Head Split Backing Ring	Floating Head Pull-through Bundle
Provision for differential expansion	Individual tubes free to expand	Expansion joint in shell	Floating head	Floating head
Removable bundle	Yes	No	Yes	Yes
Replacement bundle possible	Yes	Not practical	Yes	Yes
Individual tubes replaceable	Only those in outside row	Yes	Yes	Yes
Tube interiors cleanable	Difficult to do mechanically, can be done chemically	Yes, mechanically or chemically	Yes, mechanically or chemically	Yes, mechanically or chemically

Well, one thing is before you decide D s and before you arrange for the decide on the arrangement it is important that you have decided the type of shell and tube heat exchanger. Whether you are going for a U tube or a fixed tube or a floating head whatever it is that has to be decided. This has been amply discussed during the introduction of the shell and tube exchangers.

I will not be going into the details fixed tube sheet naturally it is going to be it is going to be the cheapest, but in this case mechanical or chemical cleaning it is particularly the bundle it is not removable that is the only main problem here, otherwise we will go for a fixed tube sheet. In any case if you do not adopt a fixed tube sheet then depending upon the advantages and the limitations we will be selecting either a U tube or a floating head.

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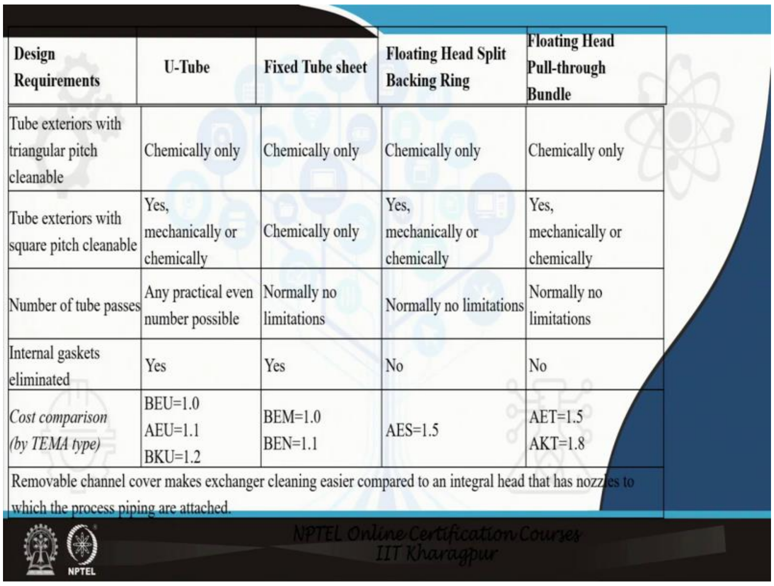

Design Requirements	U-Tube	Fixed Tube sheet	Floating Head Split Backing Ring	Floating Head Pull-through Bundle
Tube exteriors with triangular pitch cleanable	Chemically only	Chemically only	Chemically only	Chemically only
Tube exteriors with square pitch cleanable	Yes, mechanically or chemically	Chemically only	Yes, mechanically or chemically	Yes, mechanically or chemically
Number of tube passes	Any practical even number possible	Normally no limitations	Normally no limitations	Normally no limitations
Internal gaskets eliminated	Yes	Yes	No	No
Cost comparison (by TEMA type)	BEU=1.0 AEU=1.1 BKU=1.2	BEM=1.0 BEN=1.1	AES=1.5	AET=1.5 AKT=1.8
Removable channel cover makes exchanger cleaning easier compared to an integral head that has nozzles to which the process piping are attached.				

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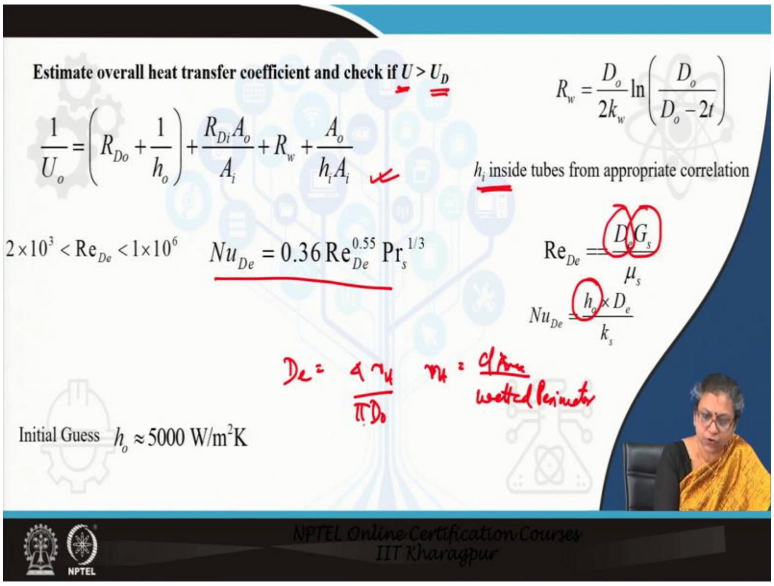

So, therefore, different parameters on which you are going to base are there you can refer to this table when you go for selection of the heat exchange the type of the heat exchanger. After you select only the tube pitch the tube layout all those things will be finalized and then you find out the shell diameter. Once everything is done the all the geometric parameters have been defined.

So, now, there are two things you know that you have to do, one is to find out the overall heat transfer coefficient. Remember you had started with some particular assumption, check if the as the whatever you had assumed and whatever you have now found out whether now whatever you are finding out is greater than the design value that you have assumed in that case there is sufficient margin you can proceed.

If no then possibly you have to check the design change the tube diameters etcetera, etcetera and proceed with the geometric parameters once more. Now, finding out this particular U it is pretty simple, we always find it out in terms of the outside diameter of the inner tube. So, for an unfinished shell and tube heat exchanger this is the general formula the same for the double pipe as well as for the shell and tube.

Finding out h i is no big deal we will do it in the same particular way. For finding out the h o for the outside what you need to do, you need to find out the you can go for this particular formula. Now, in this particular equation what are the things that you need to find out, one is definitely finding out D e the other is finding out G s. Once these two can be worked out then generally we can go ahead with this right.

Now, to find out D e what is D e it is the equivalent diameter or the equi periphery diameter in whatever way you can you wish you can define it is nothing, but the, four times again I repeat this I have here done earlier 4 r H where, r H this is equals to cross sectional area divided by the wetted perimeter.

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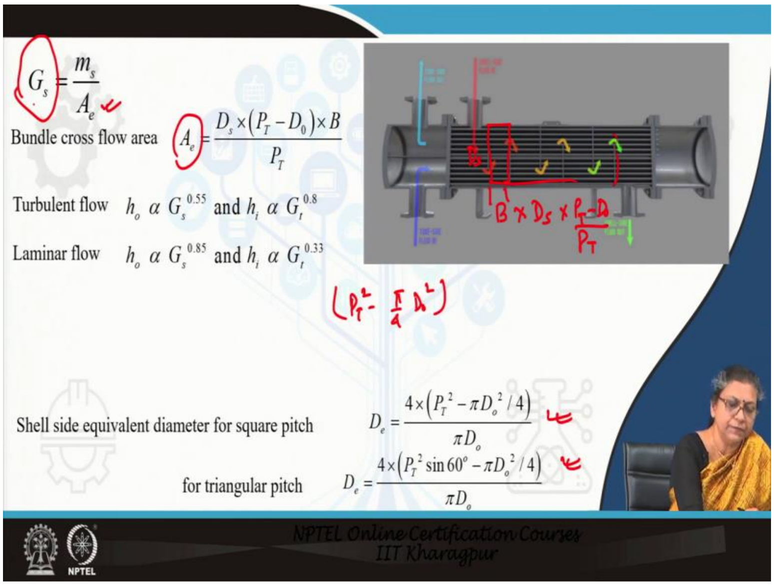

What is the cross sectional area in this particular in this particular case if you find, what is the cross sectional area again? The cross sectional area it is going to be P T square minus pi by 4 D o square right. And what is the wetted cross section in this particular case, if you consider what will be the wetted perimeter, wetted perimeter will naturally be the tube od so pi D o.

So therefore, from there if you divide one with the other for the square pitch and for the triangular pitch you can find out the equivalent diameter by considering the cross sectional area and the wetted perimeter fine. The next is the mass flux which is the mass flow rate divided by A e. Now, tell me one thing what is this A e? This A e it is actually the flow cross section, the bundle flow cross area through which the shell is flowing.

It is true that the shell is entering on one side it is flowing along it is coming down the other side, but normally if you consider the flow area across which this is flowing then it is basically say it is basically this particular area right. So, for finding out the bundle flow cross section for DVD, if suppose we take the area between two particular baffles. The baffle spacing it is equal to B right.

So, therefore, normally D s into B is the area which should be the cross flow area which is available for the tubes it should be B into D s this is D s and this is B agreed. But this whole area it is not available for cross flow why? Because number of tubes are there so, therefore, what is the fraction of the area that is available for cross flow it is naturally equals to B into D s into the fraction will be P T minus D o by P T. So, from here you can find out the bundle flow cross area, once bundle flow cross area can be found out then you can find out the mass velocity.

And once the mass velocity is found out then here you find this you can you this is the property group all other properties can be found out and you can find out h o. h i has been found out h o has been found out the other terms are pretty simple you can find out U 0 once U 0 is found out you can make this check.

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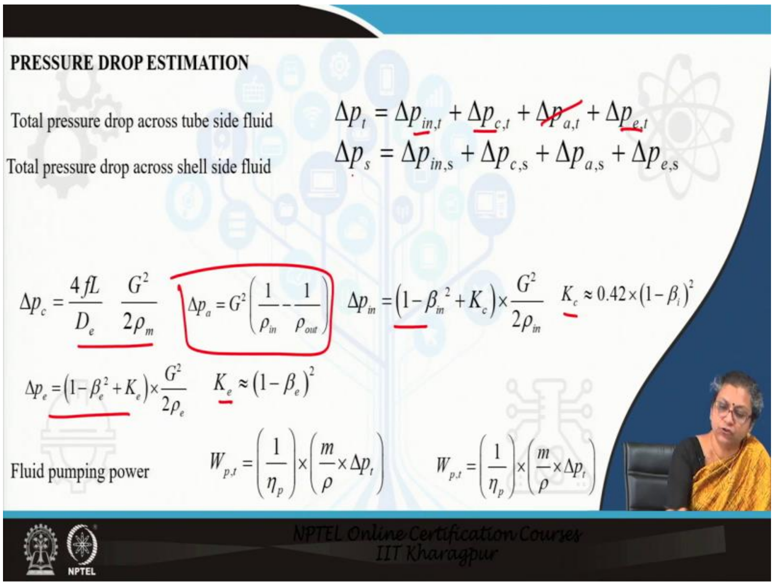

If this check it complies then in that case you are lucky, you can go ahead and do the pressure drop calculations. What are the pressure drop calculations? We had already discussed this during double pipe, it is the straight pipe pressure drop or the core pressure drop as it is said.

There has to be some entry losses there has to be some exit losses, regarding the entry and the exit losses they have been expressed in terms of expansion coefficient and contraction coefficient and the ratio of the area by the frontal area beta. So, therefore, and these are the expressions for the coefficients for the straight section you already know what should be the expression.

Suppose, there is some particular acceleration pressure drop due to significant change of the fluid density from the inlet to the outlet this normally will not happen, if that is there then only this part comes otherwise this part generally it can be neglected. Same formula applies for the tube side and the shell side. So, from here you can find out the pressure drop you can find out the fluid pumping power as well.

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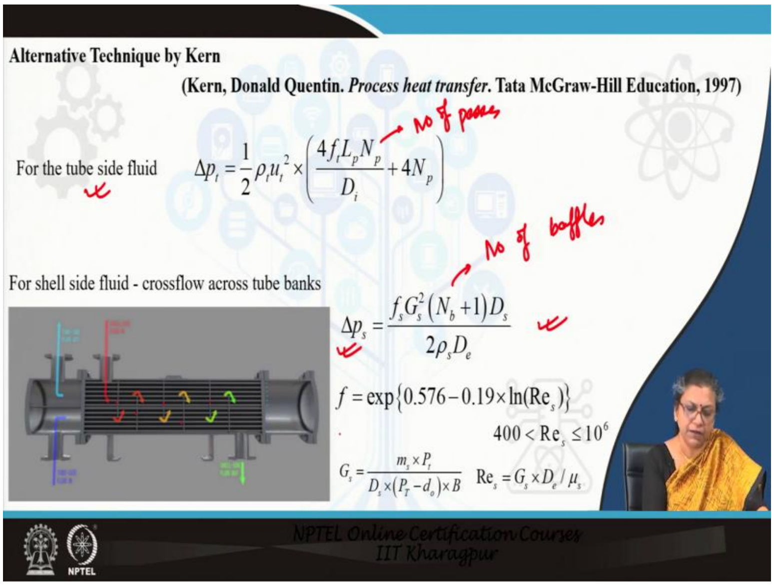

Well Kern had suggested another particular expression where the pressure drop across the return bends were considered as fraction of the pressure drop or a or some multiple of the pressure drop for the straight pipe. And accordingly he had suggested the tube side fluid pressure drop by this expression the shell side fluid pressure drop for cross flow across the banks by this expression N p it this is the number of passes and N b is the number of baffles.

So, therefore, in this particular case you will find that it is the straight pressure drop into the number of times the shell side fluid is changing the direction. So, in this case 1 2 3 4 5 6 number of baffles are there, and the number of times the changing is 1 2 3 4 5 6 7.

So, therefore, in that particular way your number of times the fluid changes it is direction its N b plus 1 and accordingly the shell side pressure drop has been found out where the friction factor and the mass fluxes Reynolds number they are they have already been discussed there is nothing more for me to do. So, the pressure drop has also been found out.

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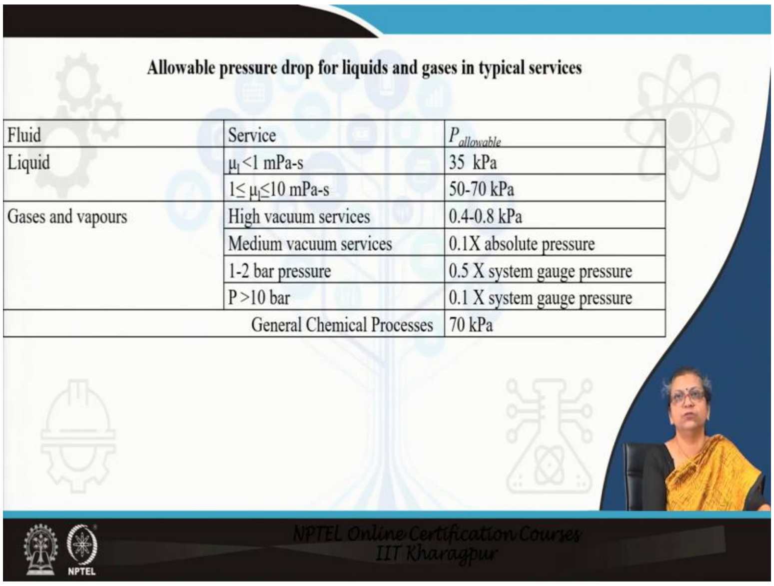

Next check is what to find out whether the pressure drop that you have estimated lies within the allowable pressure drop. Either the allowable pressure drop will be provided in your problem or else you need to check the allowable pressure drop and again for that the codes have provided some particular data. So, therefore, you can refer to this and find out whether the allowable pressure drop lies within these limits

If it lies within these limits again you are lucky or else you have to you have to do something, doing something means you have to increase the diameter to decrease the velocity and accordingly you have to make some adjustments or you have to increase the to in order to decrease the pipe length you have to increase the number of passes certain things have to be done. So, in that way we can go ahead.

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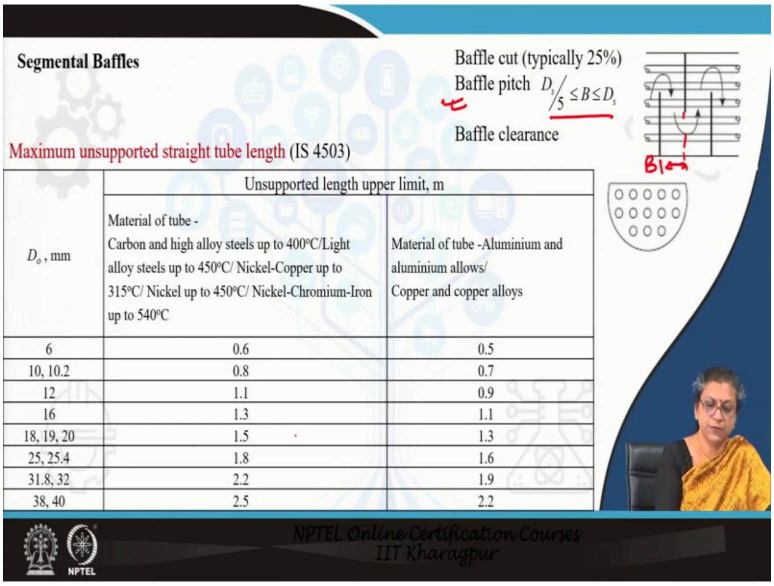

D_o, mm	Unsupported length upper limit, m	
	Material of tube - Carbon and high alloy steels up to 400°C/Light alloy steels up to 450°C/ Nickel-Copper up to 315°C/ Nickel up to 450°C/ Nickel-Chromium-Iron up to 540°C	Material of tube -Aluminium and aluminium allows/ Copper and copper alloys
6	0.6	0.5
10, 10.2	0.8	0.7
12	1.1	0.9
16	1.3	1.1
18, 19, 20	1.5	1.3
25, 25.4	1.8	1.6
31.8, 32	2.2	1.9
38, 40	2.5	2.2

Now, with this; what have we done? We have completely we have completed the thermal design we have completed the hydraulic design. There are certain other things which have to be considered before you can complete the design, one is baffles. We will be discussing just the segmental baffles in this case.

Now, in the baffles what are the things that have to be decided there are three things, one thing is pitch, what is pitch? The distance between the adjacent baffles, this is given by B. Now, and what is this going to depend? Normally, this varies between 1 5th shell diameter, to the shell diameter, but actually it depends upon the maximum unsupported straight tube length of the tube, the maximum length of the tube that can be unsupported

Because, baffles if you remember there are two purposes one purpose is that definitely it lends additional turbulence and mixing in the shell side fluid, but it also imparts structural support to the tube side fluid right. So, therefore, they have to be placed such that they lend adequate support to the tubes. So, therefore, the baffle pitch is primarily decided based on the maximum unsupported straight tube length. And again from IS 4503 there is some particular specification here, this has been specified both by IS 4503 as well as by TEMA.

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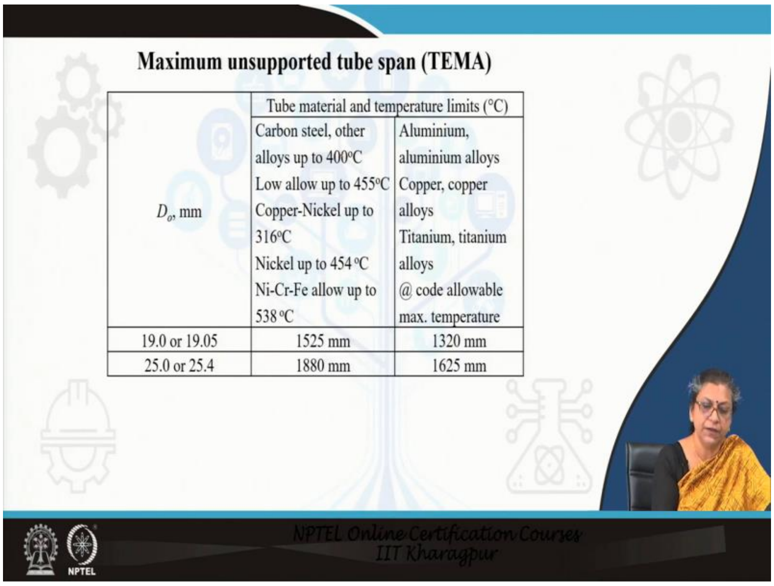

Why I am showing you this for two different codes? Just to bring it to a notice that whenever you are designing you have to follow one particular code you cannot mix up codes. There is some difference between the different codes. So, therefore, whenever you are going for a design you should follow any one particular code and then you should proceed.

Well what is the next thing, the baffle cut. The baffle cut you know the it is the amount of the circle which has been cut out to form the segmental baffle this typically is taken as 25 percent it and the other thing is baffle orientation also whether it should be a horizontal or whether it should be vertical.

Normally, if you are going for a vaporizing system it does not matter you can take either a horizontal or a vertical cut. If you are going for a condensation section quite naturally if you take a vertical cut, then it will allow the liquid to the condensing liquid to fall down it is not going to get accumulated on the baffles so we would prefer a vertical cut for your condensing systems.

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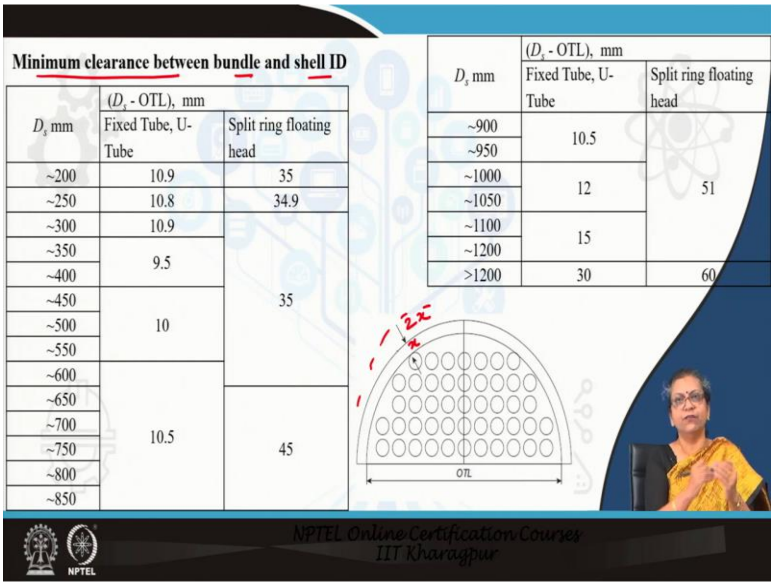

D_s mm	(D_s - OTL), mm Fixed Tube, U-Tube	Split ring floating head
~200	10.9	35
~250	10.8	34.9
~300	10.9	35
~350	9.5	
~400		
~450	10	
~500		
~550		
~600	10.5	
~650		45
~700		
~750		
~800		
~850		
~900	10.5	51
~950		
~1000	12	
~1050		
~1100	15	
~1200		
>1200	30	60

There is one other very important thing for when you are designing the baffles, what is it? You need to remember that first thing is from the outside diameter of the tube there has to be some clearance, why? Because see anyhow when the fluid is growing at such a high velocity the tubes might vibrate and if they are vibrating to such an extent that the baffle breaks away we do not want that.

So, there has to be some particular clearance normally suppose we define it by x. So, then in that case there has to be another clearance between the baffle and the outer shell. Normally, if this is x that particular clearance is taken as 2 x so that we can pull the tube without damaging the shell as I have told you.

Now, here also I have provided you another table to for the minimum clearance between the bundle and the shell ID. So, therefore, from here depending upon what type of tube you have decided we you can refer to this for the D s you can find out D s minus OTL, accordingly you can decide this particular clearance and this particular clearance. Remember one thing this is the minimum clearance that is there.

You can go for a higher clearance, but again remember if the clearance between the baffle and the outer the shell it is too much then there is a possibility that the shell side fluid it will entirely flow through the area between the baffle and the shell side and it is going to bypass the tubes.

We do not want this maldistribution of the fluids we want the shell side fluid to come in contact with the tube side fluid and remain in contact to the maximum and extent for the maximum possible heat transfer. So, therefore, we would not want a very great clearance between the baffle and the outside diameter again we would not like the baffle to be completely in touch with the outside diameter. So, accordingly this design has to be done.

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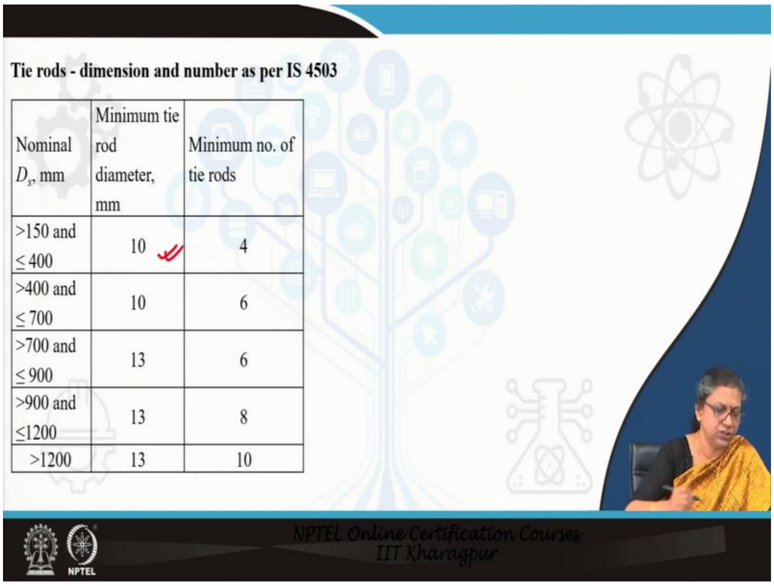

Tie rights I have nothing to say the sorry tie rods I have nothing to say just remember that the minimum number of tie rods have to be 4 and the minimum tie rod diameter it is 10 millimeters depending upon the nominal diameter of the shell we are going to decide upon the tie rods.

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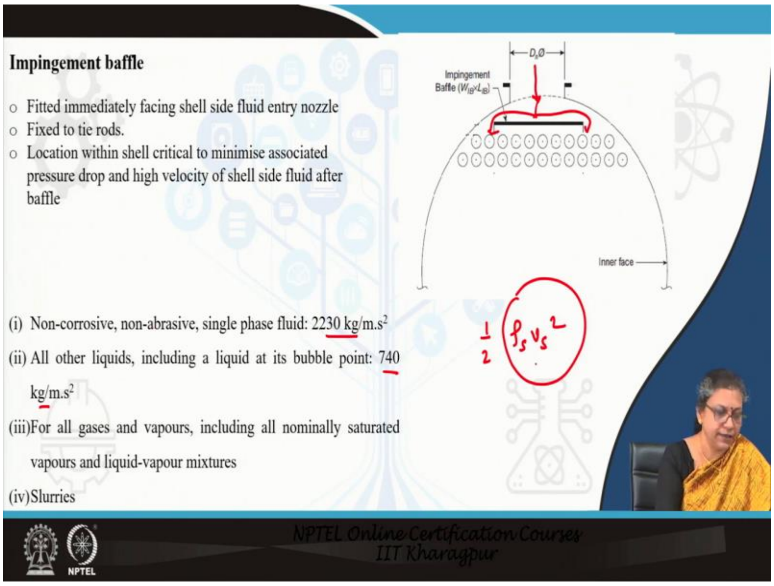

There is one important thing which was not mentioned to you I think, I will be mentioning this and then finishing off this lecture. See when from the shell side fluid the fluid is falling it falls at a very high velocity compared the nozzle is of a smaller diameter so naturally the velocity is very high. Directly it comes and it hits upon the tube on the outside. What can happen the tubes can erode away you do not want this.

So, very frequently what we do we place an impingement baffle here right. So, that so that the this fluid comes it directly strikes here and then from here it falls down so, that the velocity has slightly reduced and the tubes on the outside are saved from the great impact here.

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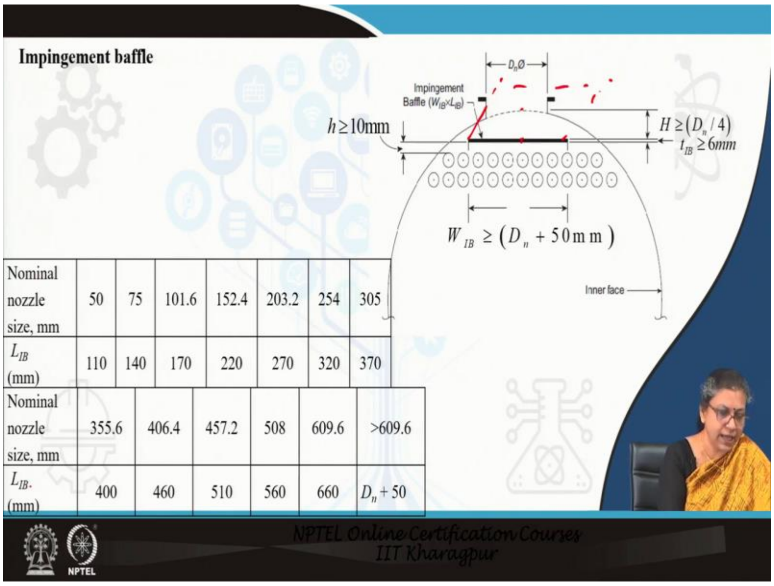

Now, for this particular impingement baffle also you see there are some fixed dimensions with respect to the nozzle diameter which have been fixed for this particular impingement baffle right. And these things they are already specified what should be the width and what should be the distance from the nozzle, the distance this distance and this distance both of them are very important right.

So, therefore, this has to be kept in mind the thickness of the baffle is specified everything from the nozzle and then, the width I have told the length on this part this also has been has been specified from the codes based on nozzle diameter you can consider these things and you can design the impingement baffle.

But remember one thing this impingement baffle it is just for the large velocity. So, therefore, the velocity of the tube it is of the shell side fluid which is falling through the nozzle it is defined as half rho s u s square right. So, whether you need a baffle or not that depends upon this particular term.

So, therefore, what you need to do? You have designed everything you have sized the nozzles you know the density and the velocity of the fluid which is falling from here you know the nozzle dimension you know the flow rate, you can find out u s, you can find out rho s u s square. Find it out and then check whether for non corrosive non aggressive single fluids this particular term is higher than this or not.

Other liquids this is the limit. If gases and vapours are there then for saturated or liquid vapour mixtures always impingement baffles are provided for slurries definitely impingement baffles will be provided because in that case the tendency of erosion will be higher. For your liquids this is the check, checkup if you think impingement baffle should be used these are the dimensions that should be respected and accordingly the design has to be made.

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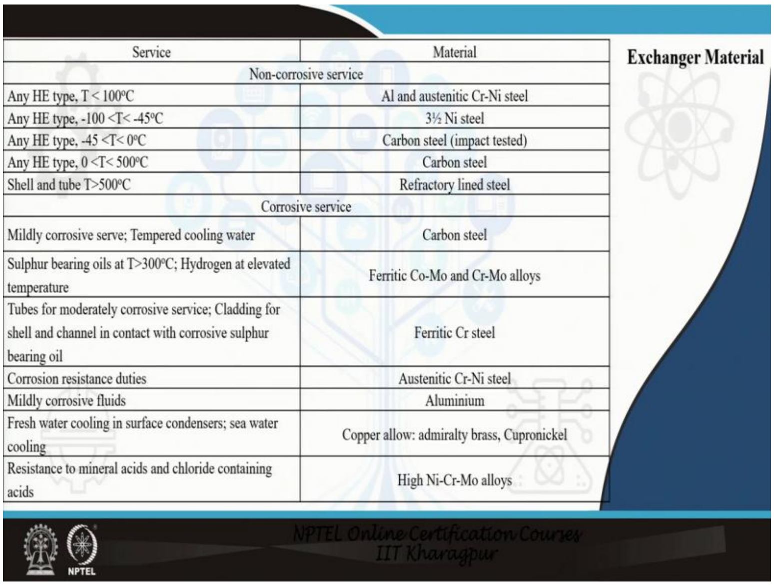

Service	Material
Non-corrosive service	
Any HE type, T < 100°C	Al and austenitic Cr-Ni steel
Any HE type, -100 <T< -45°C	3½ Ni steel
Any HE type, -45 <T< 0°C	Carbon steel (impact tested)
Any HE type, 0 <T< 500°C	Carbon steel
Shell and tube T>500°C	Refractory lined steel
Corrosive service	
Mildly corrosive serve; Tempered cooling water	Carbon steel
Sulphur bearing oils at T>300°C; Hydrogen at elevated temperature	Ferritic Co-Mo and Cr-Mo alloys
Tubes for moderately corrosive service; Cladding for shell and channel in contact with corrosive sulphur bearing oil	Ferritic Cr steel
Corrosion resistance duties	Austenitic Cr-Ni steel
Mildly corrosive fluids	Aluminium
Fresh water cooling in surface condensers; sea water cooling	Copper allow: admiralty brass, Cupronickel
Resistance to mineral acids and chloride containing acids	High Ni-Cr-Mo alloys

So, I think with this I will be ending the discussions on shell and tube heat exchanger. More or less everything has been designed or everything has been discussed. In case you have got any doubts or you want to discuss anything else you can definitely get back to us. I think you can go back to the problem, you can start working on the problem, just in the same way that I have discussed about the procedure. For any doubts we can have a discussion later on.

Thank you so much.