Heat Exchangers: Fundamentals and Design Analysis

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Lecture – 64
Heat exchanger network (Contd.)

Welcome back. So, we were working on or we were learning the Heat exchanger network analysis by pinch technique. So, the pinch point I have introduced, we have got the pinch point. Pinch point divides the problem into two parts. One is hot end problem of the heat exchanger network. Another is cold end problem of the heat exchanger network. And each of these ends can be designed separately, and the design has to be started from the pinch point. So, these were the message, I have given in the last lecture.

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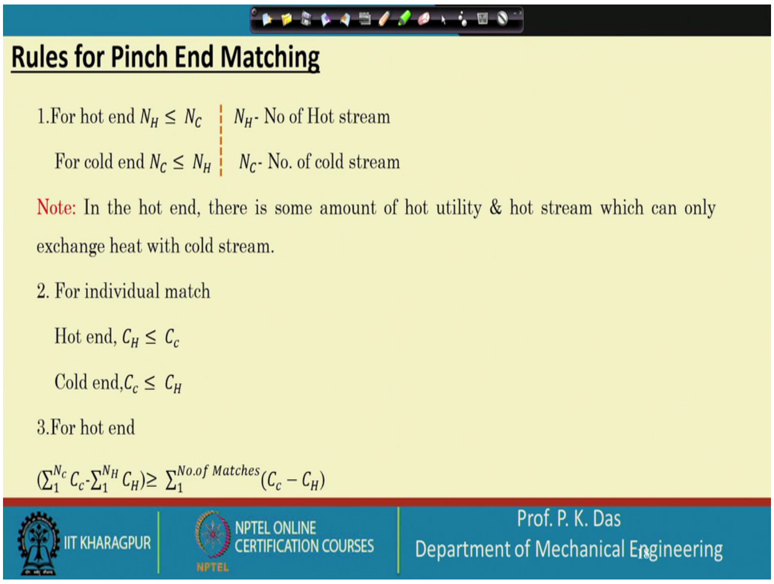

Now, let us ah look at the slide. So, rules for pinch end matching. Number of hot end number for the hot end, number of hot stream should be less than number of cold stream ok. And for cold end, number of cold stream should be equal to or less than number of hot stream. So, this is very important and why it is so. At the hot end, we cannot use any cold utility. So, if we cannot use any cold utility, all the hot streams are to be cooled with the help of cold stream only. So, number of hot stream should not be less than cold stream, and same is same holds good for the cold end.

In the hot end, there are some amount of hot utility and hot stream which can only exchange with exchange heat with cold streams, so that is what I have told that at the hot end, there is no cold utility. Hot steam can exchange heat only with the cold stream. So, the number of cold stream should be more or at least equal than the number of hot streams.

For individual match, again extending the logic one can get C H heat capacity rate of the hot stream that should be less than the heat capacity rate of the cold stream less than or equal to and at the cold end, C C that should be the less than C H. Then for hot end, this cumulative thing also has to be taken into care ok. So, for the hot end, this has to be taken into care. This is not very stringent, but generally this is also taken into care. And sorry similarly for cold end also, we will have similar type of a rule. Now, with this if we go to the next slide, we have got some example.

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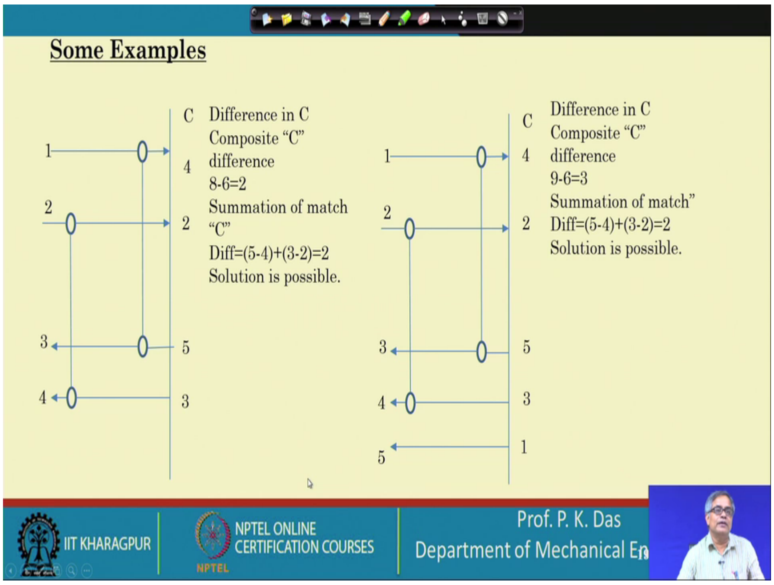

Let us say this is your hot stream, and this is another here hot stream. And we have got 4 as the heat capacity rate for the first stream, 2 as the heat capacity rate for the second stream. And for the third stream, which is a cold stream, this is 5 and this is 3. So, difference in C for composite what is the difference, difference is 8, 5 plus 3, 8 minus 6 that is 2. Summation of match C difference is this one the solution is possible in this case.

Now, if we change this value little bit or we bring in some sort of a new kind of I mean another cold stream ok. Let us go to the first one, first one first one what we are getting that first one this has got this has got what. A heat capacity rate of 4, hot stream has got a heat capacity rate of 4, cold stream has got a heat capacity rate of 5. And this is the hot end, after the pinch point. So, 5 is more than 4, solution is possible, and then cumulative thing also solution is possible. So, this is a good case.

In this case 4 5, so 5 is more than 4 that is all right. And then here also the cumulative thing if we see, then also the solution is possible. So, both the cases, we can get some sort of a solution. And in this case, what you have to see, here the number of hot streams is equal to number of cold streams. So, this is also one condition, which to be satisfied. And here the number of hot stream is less than the number of cold stream. So, this is also something which is desirable for your hot end of the pinch point. So, similarly we can proceed, we can go to the next slide.

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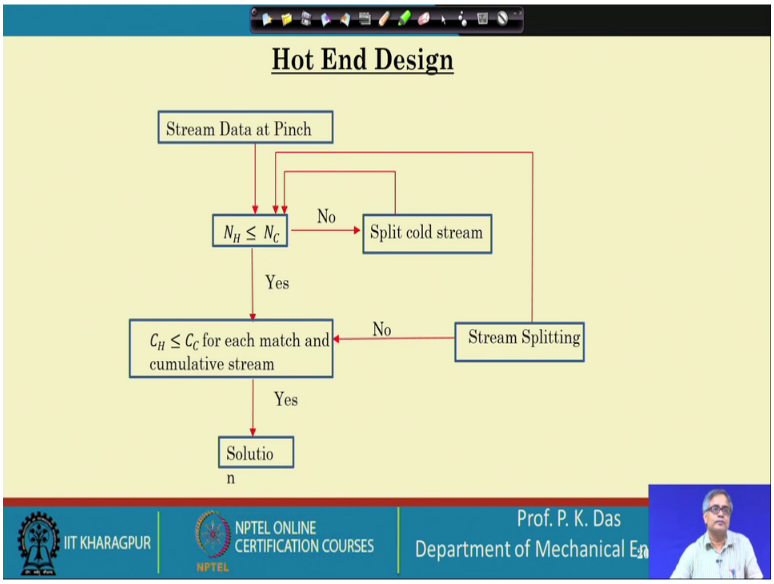

So, for hot end design, these are this is the thing. Number of hot stream should be less than equal to number of cold stream. If not then what we have to do, we have to split the cold stream. So, if we split the cold stream, then number of cold stream will increase. So, then we have to check, whether number of hot stream is higher than the number of cold stream. Then once this is be more stringent case once this is satisfied, we go to the next case. C H is less than equal to C C for each match and for cumulative stress stream yes, then we can get the solution. If not, then we have to get the stream splitting. And with this stream splitting, we have to go again to the top ok. So, this is your hot end design.

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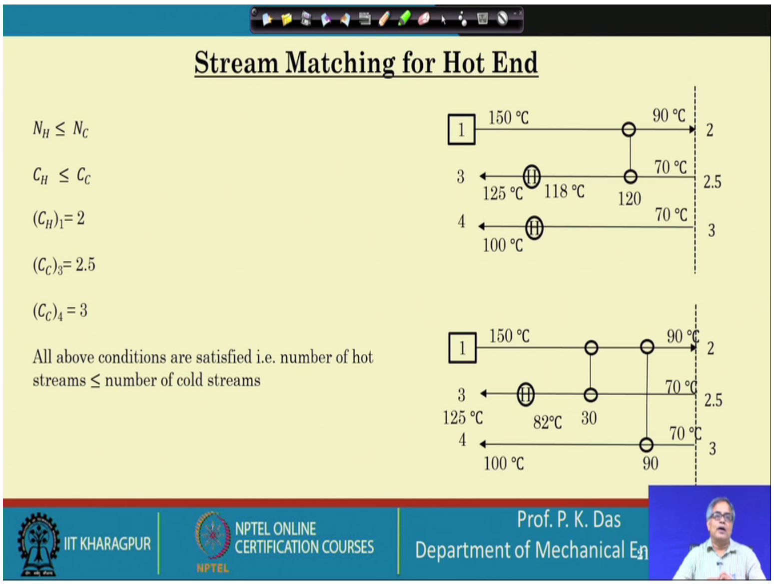

Now, let us go back for our let us go back to the problem with which we have started. So, in the hot end, we have got three stream. One hot stream starts from 150 degree Celsius, it goes to 90 degree, because this is our pinch point one cold stream start from 70 degree Celsius that is pinch point, and goes to 125 degree Celsius. Another cold stream starts from 70 degree Celsius, it goes to it has to go to 100 degree Celsius.

So, what we can have, we can have this solution between stream 1 and stream 2 we can have a heat exchanger. And we can have a heat exchanger, here the temperature difference should be 90 and this is 70 that is the pinch point. And then if we know this temperature, we know how much heat transfer can be done. And here we use some part of a philosophy, which is called tick of philosophy. What is tick of philosophy, tick of philosophy is told or just like this that we will have a matches such that at least one stream its heating or cooling requirement is satisfied.

So, let us say 150 degree has to be cool to 90 degree Celsius. So, if it has to be totally cooled with the help of a cold stream, then we can see that this stream we have used. So, how much heat exchange, we can calculate simply from the algebra. And then probably what we will get that the hot stream will be cooled from 150 degree to 90 degree Celsius, while the cold stream will be heated from 70 degree to 118 degree Celsius, but my target temperature is 125 degree Celsius.

So, what can I do, the rest of the heating of the cold stream can be done bringing one hot utility, how much hot utility is needed that also you can calculate. Then there is another cold stream, what I should do for that it has to be heated from 70 degree Celsius to 100 degree Celsius, no hot stream is available. So, I have to bring a hot utility and entire heating has to be done by the hot utility ok. How many heat exchanger I will need? I will need one heat exchanger over here, one hot utility heat exchanger, another hot utility heat exchanger, so three heat exchanger I will need.

I can go for and alternate solution. Let us say the hot stream one transfers heat with the cold stream one. Again I have told that tick of methodology I have to use, tick of logic I have to use, I can see that the third ah cold stream no this is the fourth cold stream fourth stream. So, this can be totally heated with the help of the hot stream. So, I will heat it fully from 70 degree Celsius to 100 degree Celsius ok. And how much heat is needed we can find out, so 70 degree to 100 degree that means, 30 degree temperature difference. 3 kilowatt per degree Celsius is the heat capacity rate.

So, I need 90 kilowatt of heat, but that will not cool the hot stream totally. So, hot stream is to be further cooled, and that can be done with the help of your cold stream number 3 ok. So, here 30 kilowatt of heat is to be is can be extracted. So, 30 kilowatt means here 30 kilowatt, here 90 kilowatt that means, 120 kilowatt. 150 degree is to be cooled to 90 degree Celsius temperature difference is 60. 60 into 2 that is 120 and 120 has exactly been taken from the hot stream.

But, what about the cold stream, cold stream is to be heated from 70 degree to 125 degree Celsius. So, what will happen, this is not enough, so I have to use one hot utility. So, basically again I am using three heat exchanger, but I have got two alternate solution, even more than that one can get in specific cases. And these are the flexibility of the design I am getting. More number of solution I get, then actually many of the practical things I have neglected in a plant, whatever practical things are there I have neglected.

Like two stream cannot be brought together or heat exchanger, it is very small heat capacity or with a small capacity should not be used. So, those kind of things, I have neglected. So, now I have got many alternate solution means those practical aspects, now I can see and what is the best solution I can pick up. Let us go to the next slide.

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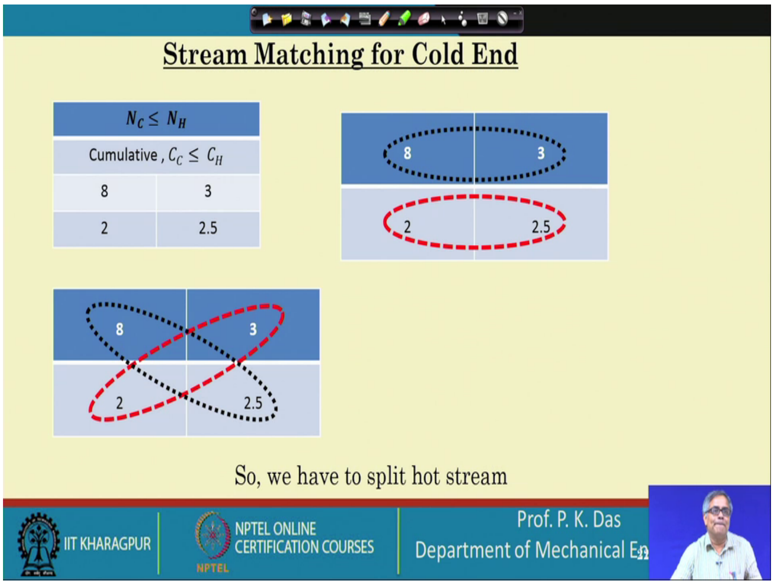

So, stream matching for cold end. Now, I am coming to the cold end. So, in the cold end, there are two hot stream and two cold stream. The hot stream and cold stream numbers are matching. So, first requirement has been satisfied ok. At the cold end, number of hot stream should not be less than the number of cold stream that has been satisfied. But, you see the hot stream this side is hot stream 3 and 2.5, I believe just let me have a look. Let us have all of us let us have a look into the problem yeah.

So, hot stream one is 2, one is 2.5. And cold stream one is 3; and another is 8. I believe, yeah; 2 and 2.5 hot stream, and 8 and 3 is cold stream. Now, if I like to match that 8 and 2; 3 and 2.5, what is happening 8 is more than 3 this is good, but 2 is not more than 2.5, so this is not good. So, this is not we are not getting the solution over here. 8 is more than 2.5 here we are getting a solution, sorry 8 is the cold side, and 2.5 is the side hot side should be more. So, here this is not a solution and this also. This is a solution, because hot side is more than the cold side.

But, in both of the cases, one side we cannot match. In one match in this match let us say in this match, we are not getting solution. But, this give solution, because hot side is more than cold side. If we switch over or if we just make it rivers, then 2 and 3, 3 is the hot more than 2 this gives you the solution, but 2.5 is less than 8 that that does not give the solution. So, we have to split the hot stream, number of hot stream has to be made more. So, let us see how we can do it.

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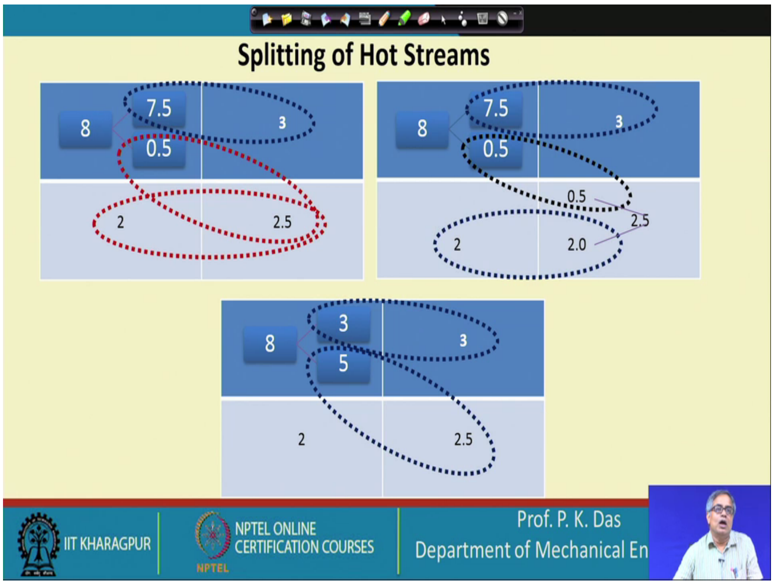

We can do split hot stream also, we can split cold stream also. Let us see, how we can do. If I split the cold stream, now if I split the cold stream, then what we are getting 8 let us split it 7.5, 0.5 and 2, and this side it is 3 and 2.5. Now, 3 is more than 3 is not more than 7.5. So, this is not a good solution. 2.5 is more than 2, 2.5 is more than 0.5. So, again this is not a some sort of a viable solution.

So, here what we do here what we do is that les see just a minute well one hot stream is 2, another hot stream that is the heat capacity rate of one hot stream is 2, cold stream is 2.5 and 3, and another hot stream is 8. So, let us keep this in mind. One hot stream is 2, another hot stream is 8. One cold stream is 2.5, another cold stream is 3, so if we keep it in mind. So, hot stream we are splitting 7.5 and 5, and then this is 2. So, there are three streams, number of hot streams are more compared to number of cold stream. And sorry this can give a viable solution, because hot stream 7.5 and this is 3, but this cannot give a viable solution, because this is your cold stream. And it is less than 0.5 less than 2.

So, now we can have 7.5 and 0.5 and here also we are splitting it. Let us say this is 3, but we have got three 0.5 and 2. So, 7.5 and 3, it can make a match, 0.5, 0.5 it can make a match, and 2 and 2 that can also make a match or what we can do 8 can be hot stream can be split into 3 and 5. So, 3 and 3 can make a match, this 3 is equal to 3. This 5 and

2.5 make a match, because if this is your more than the 2.5. So, this is also a viable solution.

So, all the viable solution, we can we have shown. So, in any case hot stream has to be split. Cold stream we may split, we may not split. So, two solution I have shown that in which cold stream has not been split. In this case, cold stream has not been split. In this case, cold stream has not been split. In this case, the cold stream has also been split. But, by splitting the cold stream, the number of the total number of the cold stream should not be more than the number of the hot streams ok, with this let us go to the next solution.

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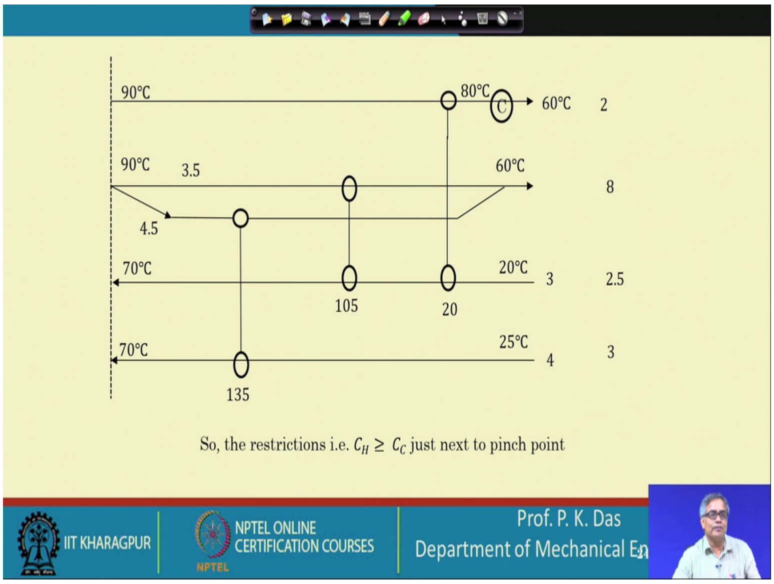

So, hot stream I have to split, and which hot stream I have to split. Here what we can see that there is a hot stream with 8 kilowatt per degree Celsius, it capacity rate that hot stream I have to split. Now, we have got the cold end solution. This is one hot stream; it starts from 90 degree Celsius that is the pinch point goes to 60 degree Celsius. Another hot stream, it starts from 90 degree Celsius goes to 60 degree Celsius, its heat capacity rate is 8.

And we have seen this has to be split, so we have splitted it. And if we have splitted, splitted it, the pinch point near the pinch point, we will have some sort of a matching between the hot stream and the cold stream. With that we can tick of the cold stream number 4 totally total heating requirement of the cold stream from 25 degree Celsius to 70 degree Celsius with a heat capacity rate of 3 that I can satisfy ok.

Now, then we have to think of the cold stream number 3. So, it can it requires two heat exchanger just like this as I have shown, but with all these things the second hot stream, which is which is actually this is 1, this is 2. So, the second hot stream can be totally cool to 60 degree Celsius, but the first hot stream cannot be cool to 60 degree Celsius. So, we need some sort of a cold utility. With the cold utility, we will be able to cool it from 80 degree to 60 degree Celsius. So, you see how many heat exchangers we needed, 1, 2, 3, 4. And all the end temperature of this heat exchange we can get ok. So, this is the solution of the cold end.

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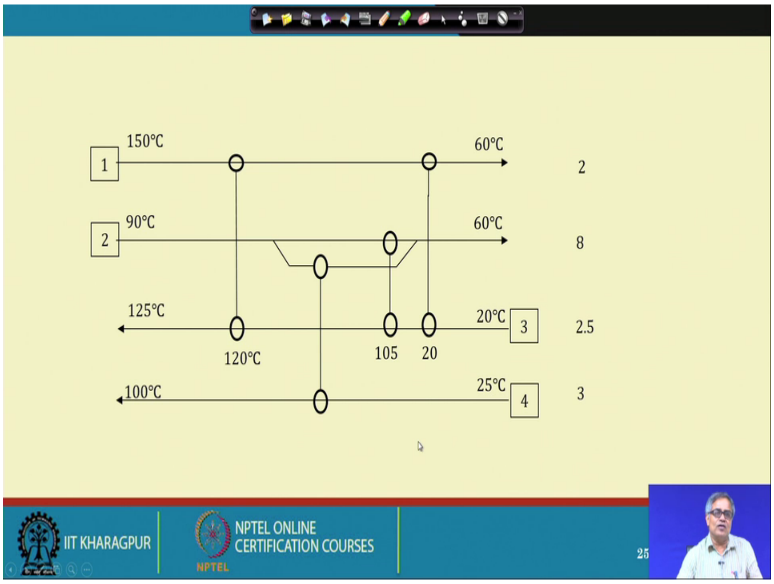

We can get another solution, but in any case as I have told that the hot stream with heat capacity rate 8 has to be split. So, this has to be split as I have shown, this has to be split Ok. Then in this case, the first hot stream is to be matched with the some sort of an intermediate one that is what we can see, this is possible. And then we have got other matches. So, this is also one kind of a solution, which is possible. And this is also one solution, which is possible.

And with this, we can get two different two different alternate for the cold end also. And with this we have got two different solution of the hot end, we have got two different solution of the cold end. And as I have told that any solution of the hot end can be combined with any solution of the cold end. So, basically whatever we have done. With that we can get four different solution of the entire heat exchanger network.

Basically, with whatever we have done, we can get four different solution of the entire network heat exchanger network. And what will the solution gives us, the solution as I have told from the problem table method, whatever we have got that is very important that we know what is the hot utility, minimum amount of hot utility to be used we get what is the minimum amount of cold utility to be utilised. So, let me recapitulate it once again.

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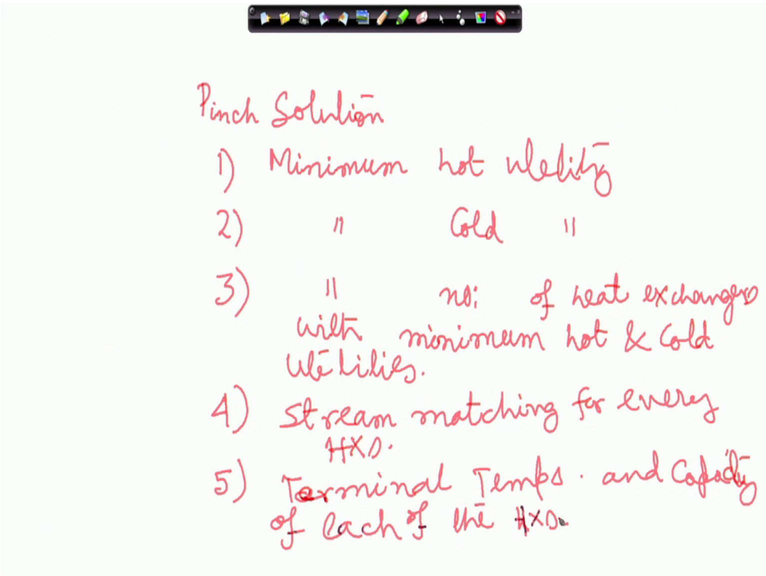

So, pinch solution what it gives, minimum hot utility, minimum cold utility, then minimum number of heat exchangers with minimum hot and cold utilities, then stream matching for every heat exchangers, then terminal temperatures and capacity of each of the heat exchangers.

So, these are the very important things, which we will get from pinch solution. Minimum hot utility, minimum cold utility, minimum number of heat exchangers with minimum hot and cold utilities, stream matching for every heat exchanger, then terminal temperature and capacity of each of the heat exchangers. More than that also we can get, like actually less last one let us see, the poor terminal temperature and ah the heat capacity. So, from there actually one can proceed towards the heat exchanger design which we have done, but more than that also we can get. Like the pinch temperature initially we have told, but pinch temperature is one thing which the designer has to select.

So, if we go for smaller pinch temperature, then more energy recovery is possible ok. But, initially the cost of the heat exchanger will be more, because we have to use better heat exchanger or larger heat exchanger. So, one can have some sort of a optimisation between the operating cost and the initial cost. And one can also decide regarding the pinch temperature, many other things are possible.

But, this is a whole course of heat exchanger here we cannot devote more time on more time on only one topic that is heat exchanger network. With this, if you go to books etcetera, there are books, there are papers. So, if you go to that further details, you will get for heat exchanger analysis.

Thank you for your attention.