Principles and Practices of Process Equipment and Plant Design
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Module - 03
Lecture - 51
Heat exchanger Network Analysis (Contd.)

Hello everybody. So, in the last class we had started the Heat Exchanger Network Analysis for the multi stream problem. And I had already told you that we had discussed this particular problem using the graphical technique of composite curves.

I had introduced you the composite curves. You have also realized yourself, you must have done the problem which was given to you, you must have found out the location of the delta p, the T pinch by this time. And I had already told you that there is a much more convenient method of this or as a substitute of this particular graphical technique for finding out the location of the delta T pinch, or to find out the pinch point.

This particular procedure - it is known as the problem table algorithm. So, today we are going to discuss the problem table algorithm.

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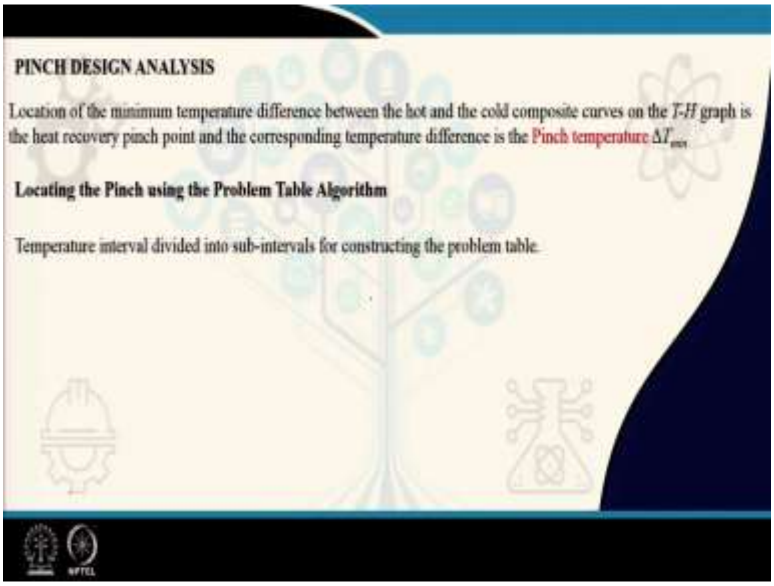

I will be starting exactly from the slide where I had ended. Now, in the problem table algorithm also the logic is almost the same.

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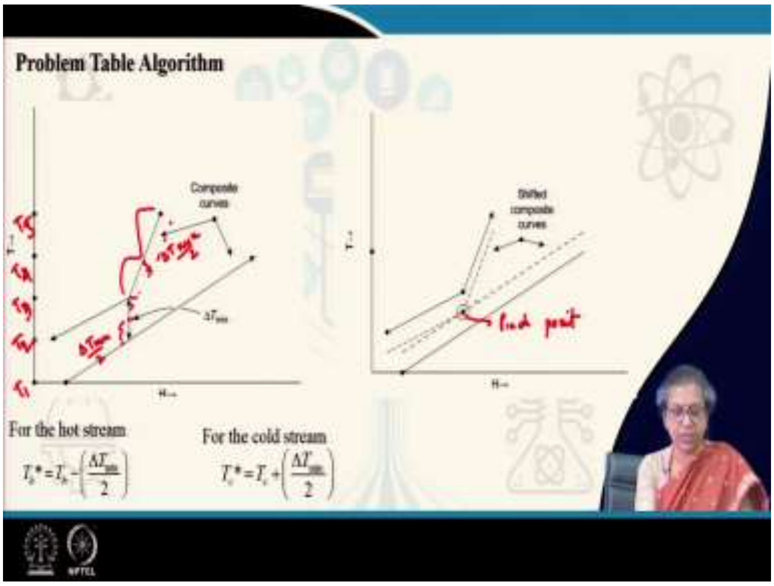

The point what is considered in this problem table algorithm is that when there is a delta T min and the cold and hot composite curves are drawn and then maybe the temperature scale is divided into a number of intervals say in this particular case it is divide into 1, 2, 3, 4 intervals etc. etc..

So, this is T 1, this is T 2, this is T 3, T 4, T 5. Then we find that in the interval from T 3 to T 5 we find that all the heat cannot be exchanged between the hot as well as the cold utilities and how, but some amount of heat will be can be transferred. What is the amount of heat that can be transferred? That depends upon the relative slope of the hot as well as the cold composite curves.

Now, in this particular case what we do is we try to bring down the hot composite curve by say, the entire hot composite curve we try to bring down by an amount of delta T min by 2. And we try to lift up the cold composite curve by an amount of say delta T min by 2. Or, in other words for all the hot streams I lower the temperature of the start and the target by delta T min by 2, for all the cold streams that is the streams which have to be heated I increase the start and the terminal temperatures by delta T min by 2.

Moment I do it what happens? I get one particular point for these two shifted composite curves which are drawn with the shifted start and target temperatures, I find that they much or rather they intersect at some particular point this particular point is my pinch point.

Now, then I once I locate the pinch point then I start making heat transfer interactions above the pinch and below the pinch and I know that this is the feasible situation because at the pinch point actually the hot the hot stream temperature is hotter than the cold stream temperature by an amount of delta T min. So, therefore, the whole situation is feasible even if we find that there is a pinch point. Now based on this the problem table algorithm has been developed.

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Now, we will be taking up the problem that I have shown you to construct or rather to find out the location of the pinch point from the using the problem table algorithm. What do I do initially? I simply lower all the start and the target temperatures of the hot stream by delta T min by 2. My delta T min I have already mentioned this is equals to 10 degree centigrade. So, therefore, delta T min by 2 it is equals to 5 degree centigrade.

So, therefore, if I do it then all the temperatures, all the start temperatures for the hot stream they are decreased by 5 degree centigrade, for the cold streams they are increased by 5 degree centigrade.

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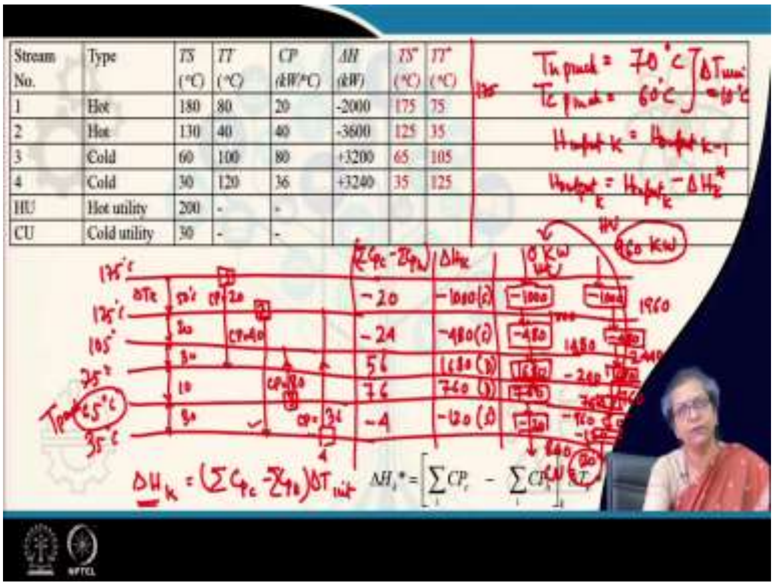

Once this is done next what I do? Next just the way I had done for the composite curve in the same way I would prefer to do this here, in the same way I start drawing a number of intervals. So, suppose I do it here, now tell me, what are the intervals which should happen here? It should be the first one should be 1 I think I will do it here, here I have got a greater space.

So, therefore, the first start temperature should be 175, after this it should be 125. Then it should be 105, then after that it should be 75, then it should be 65 then it should be 35. So, I have just drawn all the intervals in this particular case. Now, in each particular interval what is the delta T k for each interval? This in this case it is 50, in this particular case it is 20, in this particular case it is 30, in this particular case its 10, this particular case it is 30 again.

Now, let me locate all these streams along this particular intervals that I have drawn. For example, for stream 1 it starts from 175 and it ends in 75, I write down the C P also here the C P is 20. For stream 2 it starts from 125, this is stream 2 it ends in 35, what is the C P for this case? Its 40.

Stream 3 it starts from 65, this is stream 3 and it goes till 105. Stream 4 it starts from 35 it goes till 125, perfect. So, I have shown all these streams here this is the way by which you are suppose to proceed to find out the delta T, the location of delta T min by the problem table algorithm.

So, therefore, within each interval I need to find out the heat the delta H for each interval. So, therefore, delta H for the kth interval, what is this? It is definitely sigma C P c minus sigma C P minus sigma C P H into delta T of that interval. What do I, what am I trying to do? I am trying to find out whether there is any deficit or surplus heat in any particular interval.

Because if there is a deficit in heat then heat flow from the top can compensate it, if there is a surplus of heat then that violates thermodynamics. So therefore, I have put the, I have put the definition or the expression of delta H k in such a manner that within each interval if I have a minus delta H this signifies surplus, if I have a positive delta H then that signifies deficit.

So, therefore, to proceed systematically the next thing which I will be doing for each particular interval I will be finding out sigma C P c minus sigma C P h. Let us see for this I have only a hot stream no cold stream, for this I have got one particular yeah, I have got one hot, two hot streams. So, [FL] I have got two hot one cold ok. So, therefore, this for this 4 it is 36, for the 3 it is 80 C P equals to. So, therefore, for this interval it should be 36 minus 40 minus 20. So, therefore, that gives you minus 24.

Again for this interval we do not we have one hot stream and we have got two cold streams. So, therefore, this is going to be 56 for the next case we find we just have two no, I have got one hot and two cold streams again, so this is going to be 76. For the last case it is going to be minus 4 it is just one this stream and that the other stream.

So, therefore, for each interval I find this out, why I find this out? So, that I can find out delta H k for is the each interval. So, this into delta T k gives me delta H k, let me find out the delta H ks for each case, you can calculate it yourself and you can find out the delta T k, delta H k for each case. And I what do I find? I find that this denotes a surplus, this denotes a surplus, this is a deficit, this is a deficit, this is a surplus.

Now, what I do is for each interval I call them one cascade right. And we find out what is the amount of heat generation within each cascade and I find out what is the heat output from each cascade.

Now, for each cascade the heat output will be the heat input in the in that particular cascade, say if for kth cascade it is the heat input to the kth cascade minus the delta H k star in the in that cascade. All the stars they denote that we are dealing with the shifted temperatures and the enthalpy is calculated for those particular shifted temperatures where the temperatures are shifted for the hot streams by minus delta T min by 2 for the cold streams by plus delta T min by 2.

So, therefore, for each particular cascade we find that the H input for the cascade is equals to H output from just the upper cascade. So, therefore, I start numbering from the top. So, for any particular cascade we find that the heat which is entering it is the same as the heat which is coming from the upper cascade. And the heat which is going out from here is the heat which has entered here plus the delta H k star here.

So, therefore, for each cascade if we start we find that in this case the amount of heat generated is minus 1000. In fact, I can make it a little bit longer any how does not matter in this case is it is minus 480, in this case it is 1680 this is delta H k star for h cascade, this is 760 it has become a bit close that is the problem anyhow.

So, therefore, initially what I do? I start with 0 heat input from the top. So, therefore, to start with it is 0 kilowatt of the hot utility I start there. So, naturally the 0 heat is coming in here minus 1000 kilowatt has been is the delta H k. So, therefore, what comes in to the second cascade? 1000 kilowatt comes in the second cascade.

In the second cascade 1000 kilowatt comes in the heat delta H k is minus 480. So therefore, 1000 minus of minus 480, so naturally 1480 kilowatts are coming in here. From this to this we find 1480 kilowatts are coming in 1680 has is the delta H k. So, for this particular case it is minus 200, from here to here it comes we find it is minus 960 and then, what comes down here? This is 840.

Now, you try to understand one thing, what have we tried to do it here? We have tried to formulate the heat flow through a cascade where each particular cascade is bounded by the intervals which have been formed. All these particular intervals they have been formed by the shifted start and the target temperatures for the hot and cold streams which I have considered.

So, therefore, for each cascade these temperatures they have been arranged sequentially from increasing to decreasing order. And then between the cascade is formed, between two consecutive temperatures that that are there in this particular problem table. And therefore, for each cascade I have computed 1000 the it has been computed such that whenever, there is a deficit the sign of delta H k is positive whenever there is a surplus the sign of delta H k is negative. So, accordingly I formulate the heat flow here.

Now, there is something that I want you to understand. That something is that when there is heat flow from the top then if there is a deficit in heat flow that can be compensated by the heat flow from the top. But if there is a surplus then that surplus cannot be compensated by the heat flow from the top.

So, therefore, anything negative that is thermodynamically infeasible. So, therefore, in order to eliminate this these negative delta H ks for or rather this negative heat flows what do I have to do? I have to locate the maximum negative delta H which is flowing there or the maximum negative H that is flowing down and that I simply introduce on the top right.

So, therefore, what do I do? I simply from the top instead of 0 kilowatt I introduce 960 kilowatt, everything else I have kept constant, what is going to happen? The delta H ks in each interval is going to be the constant just when I introduce the maximum negative from the top, what do I do? I ensure that there are no negative heats being conducted down the line.

So, therefore, I have ruled out all sorts of thermodynamic infeasibility and I ensure that whatever heat is coming down from the top to bottom that has either a positive sign or a 0 sign. Wherever, there is a 0 sign that is the pinch, because for locating the pinch what I have done? I have brought the hot and cold composite curves such that they intersect at the pinch point.

So, therefore, this is this I do just to eliminate thermodynamic non feasibility, now what happens when I do this, when I introduce this? Again this is the same thing this is minus 1000. So, from here what comes down? 1960 kilowatt of field heat comes down, along with that what is the heat which is coming down from this cascade? It is 2440 amount of heat.

This along with 1680, what comes down? From this particular cascade 760 amount of heat, where this 760 amount of heat is coming? Here the, what is the delta H k 760, what is the amount of heat which is coming out from there it is 0.

So therefore, 0 and here the amount the delta H k is minus 120. So, what comes out from here? It is 120. So therefore, what have I done in this process? I have located the pinch point, where is the pinch point? The pinch point is at 65 degree centigrade and therefore, if T pinch is 65 degree centigrade my T hot pinch it is going to be 5 degrees above this.

So, therefore, it is going to be 70 degree centigrade, T cold pinch is going to be 5 degrees below this. So, therefore, this is going to be 60 degree centigrade, the delta T min at the pinch is respected 10 degree centigrade. And with this particular design I have found out what is the minimum amount of hot utility that has to be provided on the top in order to ensure a feasible cascade process.

Because if I this is the minimum amount of heat that I can add and ensure a feasible cascade where the heat which is flowing down from each cascade is actually a deficit heat. Which means that, from the top whatever is flowing down that is compensating the deficit heat in each cascade. And so therefore, the heat flow occurs in a from the higher temperature to the lower temperature and it is compensating the heat deficit at each and every point.

And corresponding to this hot utility what is the minimum cold utility that I have to give? This is equals to 1, 120 kilowatt. This is the most, if you recollect when I had when I was doing the same problem with the composite curve I had already shown you that the hot utility requirement was 960 kilowatt the cold utility requirement was 120 kilowatt. We have done the same thing, but in a much more simpler fashion.

Instead of sliding the curves and trying to locate this particular pinch point what we have done is, we have done it in a much more systematic or in much more convenient fashion I should say. This particular thing what it does it first lowers the hot and the cold compose and increases the hot cold composite curve such that a pinch is formed, accordingly I have done it. And then we divide the entire interval into based on the supply and the target temperatures and I also mark the heat flow in the hot and cold streams.

Then I find out the heat the delta H which is there in each particular interval or in each particular cascade. And then what I do? I try to ensure that all these cascade since they are arranged from increasing to decreasing temperature, I try to ensure that whatever heat is entering into the into the cascade that can compensate the deficit heat here inside, so that I can ensure a heat flow from a higher to a lower temperature.

So, therefore, basing this what I do? First I find out I rather try to find out the heat flow with 0 by hot utility and then whenever I find that there is something negative I know that is not feasible. So therefore, I locate all the negative delta H which is flowing down I identify the maximum negative that I have I put that as the hot utility.

So, that in that process I ensure that whatever is flowing down the cascade from the higher to the lower temperature it is compensating the heat deficit and it is not creating a heat surplus. Accordingly, I can locate the hot utility it is nothing but the maximum negative which is generated in this particular cascade.

And as of from heat balance whatever heat has to be eliminated that is the heat which has to be recovered by the cold utility. It is not that I have to give 960 you can give 1060, you can give 2000 kilowatt, but whatever additional you give the same by the same amount of cold utilities also going to increase right. This is just the minimum that I have located well. So, this is the way by which we locate the pinch point.

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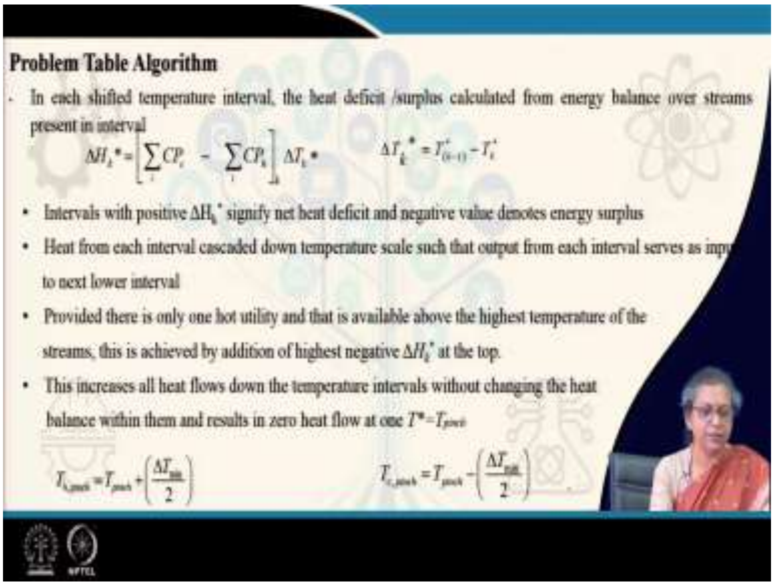

Now, once the pinch point has been located this is the; this is just I have written down I will not read through it.

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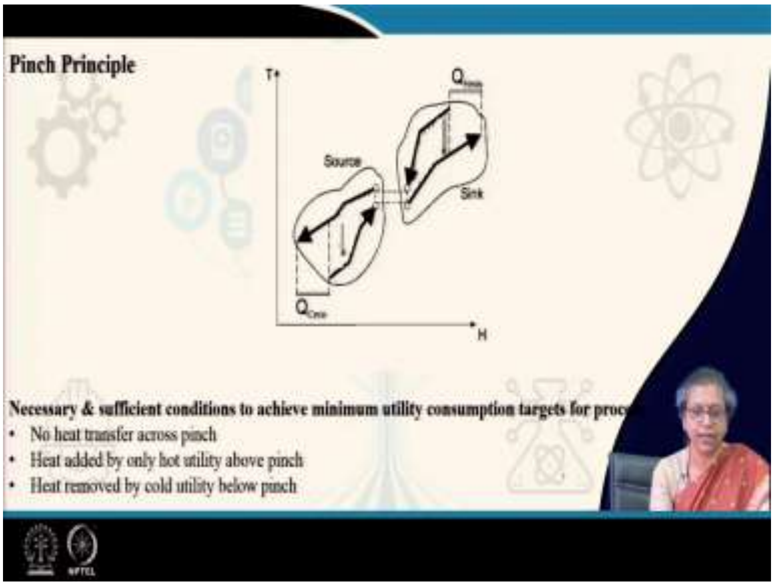

Once the pinch point is located then the design becomes pretty simple, then what we do? I will discuss it in the next class then what we do, we start matching the heat the streams below the pinch and above the pinch and identify what are the number of heat exchangers that we that we need and across which streams should I put the heat exchangers right. So therefore, then the whole problem gets divided to a cold end problem and to a hot end problem that is below the pinch and above the pinch.

Now, once I have located the pinch I have divided the whole problem then I start matching the streams and start finding out. Because you will notice that every stream there is an optimum way of matching. And to arrive at the optimum also there has there is a particular process which will ensure that you are arriving at the optimum. Just like that there is a logical procedure for finding out the pinch temperature, there is also a logical procedure for pairing the heat exchangers above the pinch and below the pinch this we are going to do in the next class.

Now, I will just end up this particular class by just leaving a question for you. See the whole thing is based on the composite curves where the composite curves they are linear. This is the first thing we have been repeatedly telling that the C P h for each particular interval the C P c for each particular interval both of them they have to be constant such that the curves are linear.

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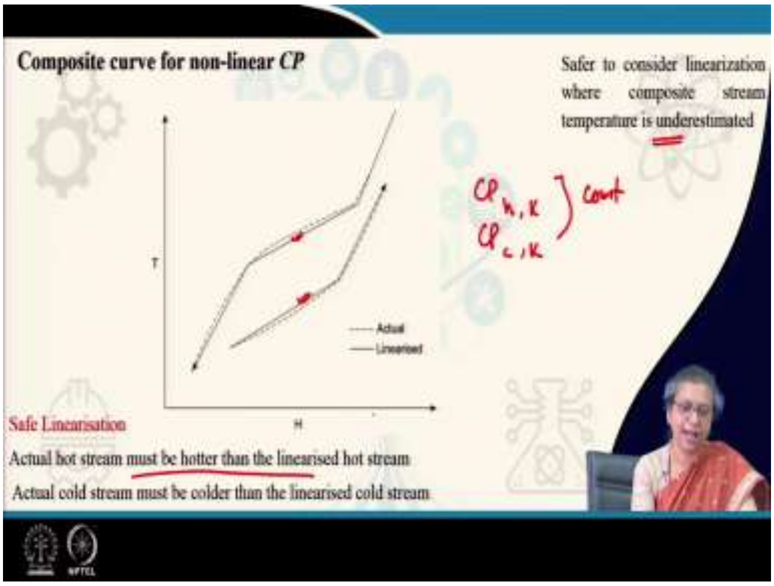

In industries there can be a high chance where the curves they are not linear. Say suppose, we are working with a mixture which is vaporizing or which is condensing under that condition will not get a linear curve.

How to draw the composite curve under that case? What we do? We simply break the non-linear curve into small small segments which are linear right and then we do the rather we perform the pinch analysis across these curves. Now, when we are breaking them into small small considerations just for the safe design it is very important to ensure that the composite stream temperatures are always underestimate, so that we get a safe design.

So, therefore, for safe linearisation we will find that the actual hot stream must always be hotter than the linearised hot stream. Or, in other words we will find that the linearised curve will be below the actual hot composite curve. And for the case of the cold stream you will find that the actual cold steam must be colder than the linearised cold stream.

In other words, the linearised cold stream should always lie above the actual cold stream. And then we have to perform the pinch analysis between this linearised hot stream and this linearised cold stream.

So, this is all that I have to I had to tell you for this class, in the next class we are going to we have already identified the pinch and what we are going to do? We are going to perform the pinch analysis above and below the pinch and identify the correct peers of these streams across which if we perform the heat exchangers we are going to arrive at the minimum number of exchangers, with the minimum with the minimum number of the minimum area of the exchangers.

Thank you very much.