Plant Design and Economics
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Lecture No -49
The Heat Recovery Pinch and The Grand Composite Curve

Welcome to lecture 49 of plant design and economics. In this module 10, we have been talking about heat exchanger networks synthesis. As of now we have learned how to determine the minimum utility targets, hot utility target, cold utility targets and also the maximum energy recovery. We have learnt through tools such as composite curves as well as problem table algorithm.

In today's lecture, we will learn about heat recovery pinch, its significance. So significance of pinch and also we will learn about another important tool again a graphical tool known as The Grand Composite curve. This will allow us to understand how to make use of multiple utilities, how to select or place multiple utilities.

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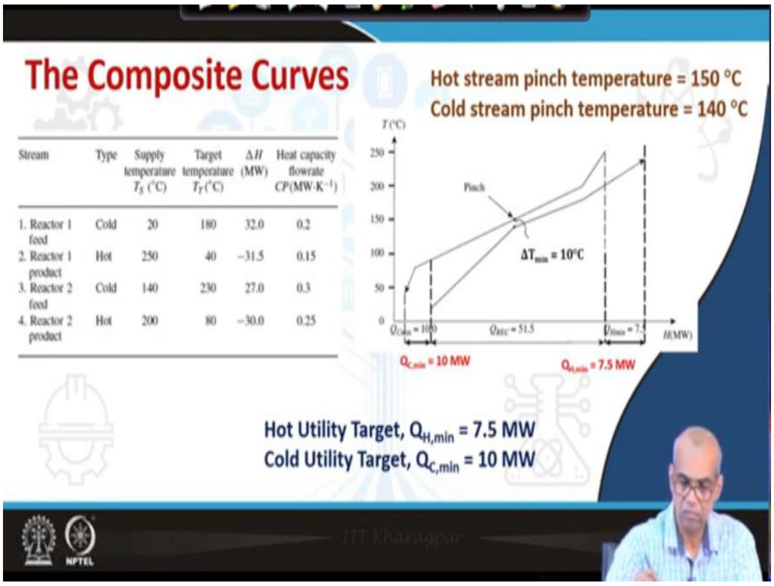

The Composite Curves

Hot stream pinch temperature = 150 °C
Cold stream pinch temperature = 140 °C

Stream	Type	Supply temperature T_S (°C)	Target temperature T_T (°C)	ΔH (MW)	Heat capacity flowrate CP(MW·K^{-1})
1. Reactor 1 feed	Cold	20	180	32.0	0.2
2. Reactor 1 product	Hot	250	40	−31.5	0.15
3. Reactor 2 feed	Cold	140	230	27.0	0.3
4. Reactor 2 product	Hot	200	80	−30.0	0.25

Hot Utility Target, $Q_{H,min}$ = 7.5 MW
Cold Utility Target, $Q_{C,min}$ = 10 MW

We have seen using a problem with 2 hot streams and 2 cold streams, the construction of composite curves. Given a minimum temperature difference for this example, it is 10 degree Celsius. We will find out the relative position between these 2 composite curves such that the vertical distance, the minimum vertical distance is exactly 10 degrees Celsius between these 2 curves.

At that point we get the hot stream pinch temperature as 150 degree Celsius and the cold stream pinch temperature of 140 degree Celsius. So, we call this as pinch. We also get the hot utility target of 7.5 megawatt and the cold utility target of 10 megawatt.

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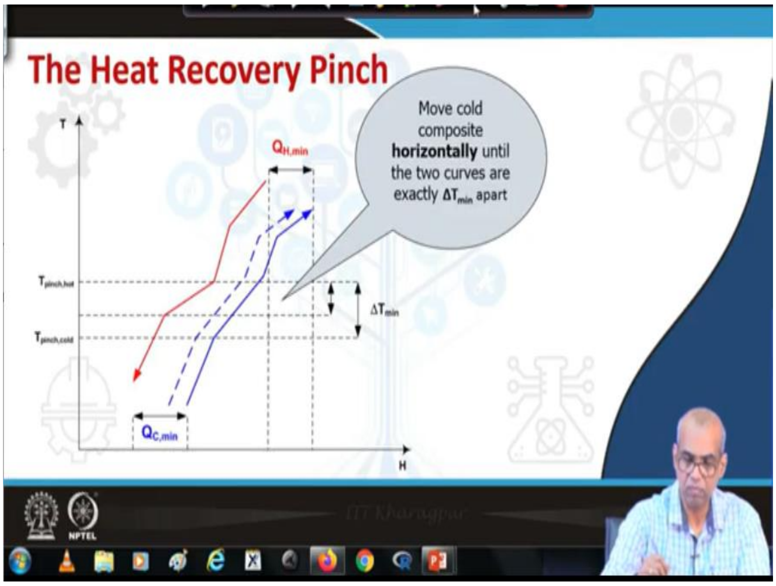

The Heat Recovery Pinch

Move cold composite **horizontally** until the two curves are exactly ΔT_{min} apart

So these informations can also be obtained from the problem table method. To determine the pinch what you can do is, we can move this composite curves horizontally and take them to a relative position where the 2 curves are exactly delta T minimum apart. You can move either of the curves, but normally will keep the hot composite curve fixed and we move the cold composite curve.

And we move the cold composite curve until the vertical distance between these 2 curves is the delta T minimum specified. And at that stage we will have the pinch point, the pinch temperature for the hot stream as well as the pinch temperature for the cold steam. Either this or either these depending on whether you have this as specified delta minimum, or this as specified delta minimum.

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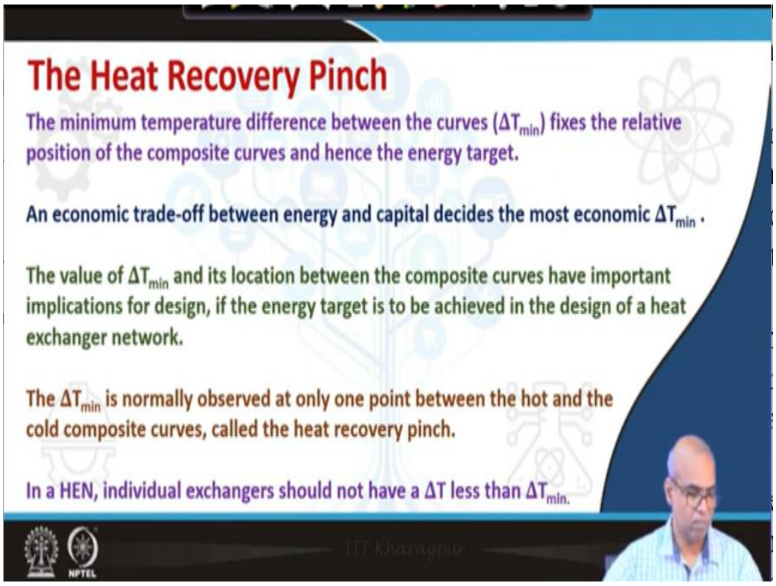

The Heat Recovery Pinch

The minimum temperature difference between the curves (ΔT_{min}) fixes the relative position of the composite curves and hence the energy target.

An economic trade-off between energy and capital decides the most economic ΔT_{min} .

The value of ΔT_{min} and its location between the composite curves have important implications for design, if the energy target is to be achieved in the design of a heat exchanger network.

The ΔT_{min} is normally observed at only one point between the hot and the cold composite curves, called the heat recovery pinch.

In a HEN, individual exchangers should not have a ΔT less than ΔT_{min}.

So what we see that the minimum temperature difference between the curves that is the delta T minimum, we will fix the relative position of the composite curves. So the relative positions of the composite curves are fixed. This also fixes the energy target. So the amount of energy that is recovered or exchange between 2 process streams becomes fixed, also hot utility target and cold utility target becomes fixed.

As we change delta T minimum, note that these utilities and the amount of heat recovered will be changing. As delta T minimum decreases there will be greater degree of overlap between hot composite curve and cold composite curve, it means that the greater amount of heat will be exchange or recovered. So that will of course reduce the utility targets. So we will save on operating cost.

But we need a bigger size heat exchanger. So the capital cost will increase. So, what will be the most economic delta T minimum? Will depend on an economic trade-off between the energy and capital cost. The value of the delta T minimum and its location between the composite curves have very important implications for design. The delta T minimum is normally observed at only 1 point between the hot composite curve and the cold composite curves.

We call that the pinch or the heat recovery pinch. Once we have fixed the minimum temperature difference delta T minimum, it will mean that any heat exchanger in a heat exchanger network must not have a temperature difference less than the specified delta T minimum.

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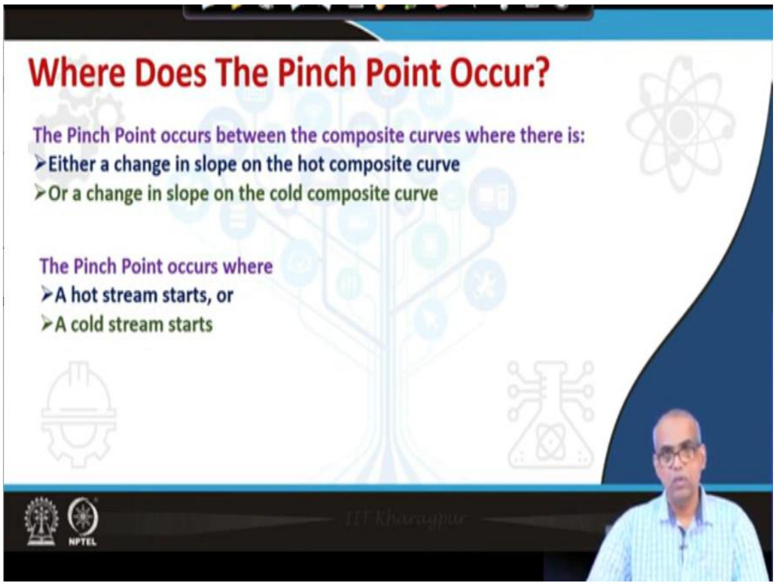

Where Does The Pinch Point Occur?

The Pinch Point occurs between the composite curves where there is:

- Either a change in slope on the hot composite curve
- Or a change in slope on the cold composite curve

The Pinch Point occurs where

- A hot stream starts, or
- A cold stream starts

Where does this pinch point generally occur? The pinch point occurs between the composite curves, between the hot composite curve and the cold composite curves where there is either a change in slope of the hot composite curve or a change in slope on the cold composite curve. So in either of these curves, change its slope a pinch point may occur. So the pinch point occurs when a hot stream starts or a cold stream starts because these 2 conditions becomes equivalent.

So when you find out the minimum vertical distance between these 2 curves as the specified delta T minimum, we will notice that a hot stream starts or a cold stem starts. Either there is a change in slope on the hot composite curve or there is a change in slope on the cold composite curve.

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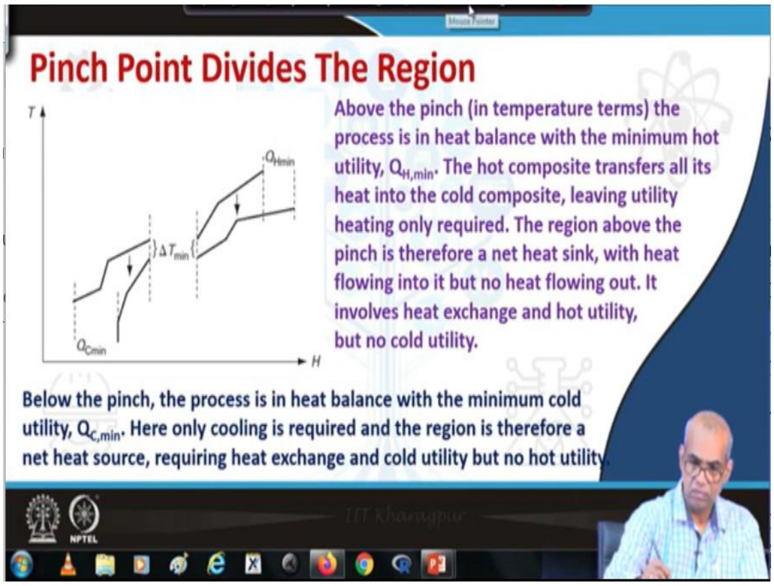

Pinch Point Divides The Region

Above the pinch (in temperature terms) the process is in heat balance with the minimum hot utility, $Q_{H,min}$. The hot composite transfers all its heat into the cold composite, leaving utility heating only required. The region above the pinch is therefore a net heat sink, with heat flowing into it but no heat flowing out. It involves heat exchange and hot utility, but no cold utility.

Below the pinch, the process is in heat balance with the minimum cold utility, $Q_{C,min}$. Here only cooling is required and the region is therefore a net heat source, requiring heat exchange and cold utility but no hot utility.

Now, let us try to understand the significance of this pinch. What you see in this figure that the 2 separated regions are shown. These 2 separated regions are connected at the pinch. We say that the pinch point divides the region into two, one region is above the pinch and the other region is below the pinch. In the region above the pinch the process is in heat balance with the minimum hot utility QH minimum.

The hot composite curve in this region above the pinch will transfer all its heat into the cold composite. So the only utility that is required is the, heating utility. You do not need cold utility. The reason is the hot streams will transfer all its heat to the cold streams and even then there remains a heat balance the cold streams requires additional heating will require hot utility, but we definitely do not need the cold utility.

Therefore the region above the pinch works like a net heat sink with heat flowing into the region but no heat flows out of the region. It involves heat exchange between two process streams it exchange service of hot utility but it does not use any cold utility. In the same way the region below the pinch the process is in heat balance with the minimum cold utility QC minimum.

So in this region only cooling is required. No heating is required. We only need cold utility we do not need any hot utility such as stream. Therefore the region below the pinch works like a net heat source. It requires heat exchange between two process streams, it requires cold utility, but it does not require any hot utility.

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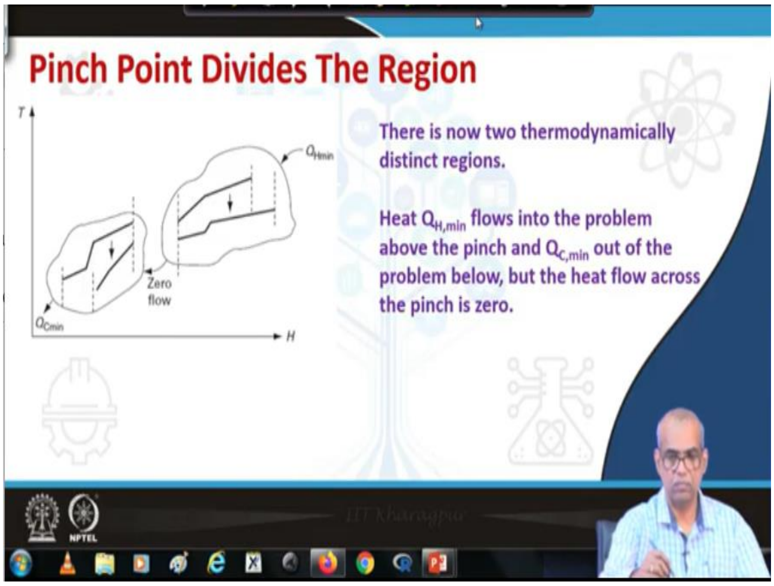

Pinch Point Divides The Region

There is now two thermodynamically distinct regions.

Heat $Q_{H,min}$ flows into the problem above the pinch and $Q_{C,min}$ out of the problem below, but the heat flow across the pinch is zero.

So therefore we have now two thermodynamically distinct regions. Heat QH minimum the minimum hot utility flows into this region above the pinch and the QC minimum flows out of the region below the pinch. And there is zero heat flow across these two across the pinch point between these two regions. So there is no heat flow across the pinch point. Heat flows into the region above the pinch, heat flows out of the region below the pinch.

Those two heat flows are above the pinch, it is hot utility target and below the pinch, it is the cold utility target. But there is no heat flow across the pinch.

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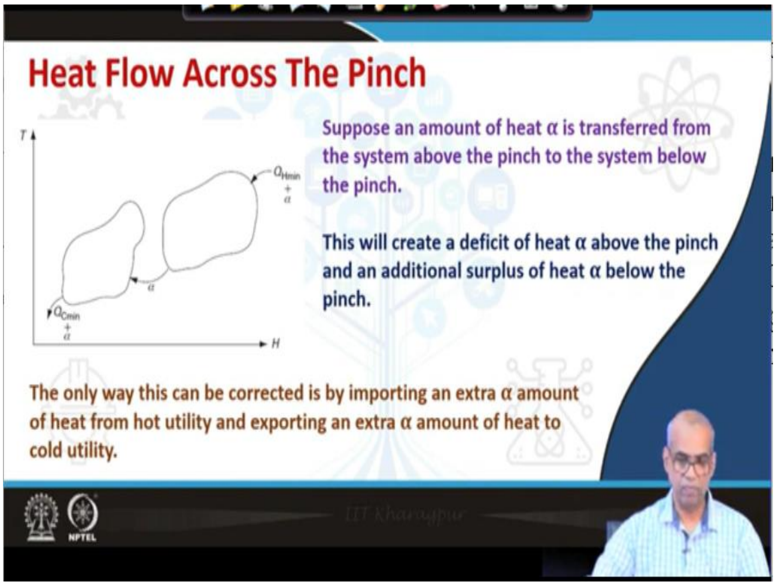

Heat Flow Across The Pinch

Suppose an amount of heat α is transferred from the system above the pinch to the system below the pinch.

This will create a deficit of heat α above the pinch and an additional surplus of heat α below the pinch.

The only way this can be corrected is by importing an extra α amount of heat from hot utility and exporting an extra α amount of heat to cold utility.

What will happen if we let flow heat across the pinch. Suppose an amount of heat say alpha is transferred from the system above the pinch to the system below the pinch. So what will happen? This will cause a deficit of heat by amount alpha in the region above the pinch. At the same time it will cause a surplus of heat by amount alpha in the region below the pinch. So how do I make a balance now?

The only way I can correct this situation is by including an extra amount of heat alpha from the hot utility in the region above the pinch and also extracting alpha amount of heat from the region below the pinch. So if I let alpha amount of heat flow from region above the pinch to region below the pinch I have to add alpha amount of heat to my minimum hot utility target, which will flow in above the region above the pinch region and I also have to extract additional alpha amount of heat from the region below the pinch.

So if I let alpha amount of heat flow across the pinch I am basically increasing both hot utility target and cold utility target by that amount alpha. So I should not let heat flow across the pinch. So this is basically doing nothing but increasing my hot utility target and cold utility target.

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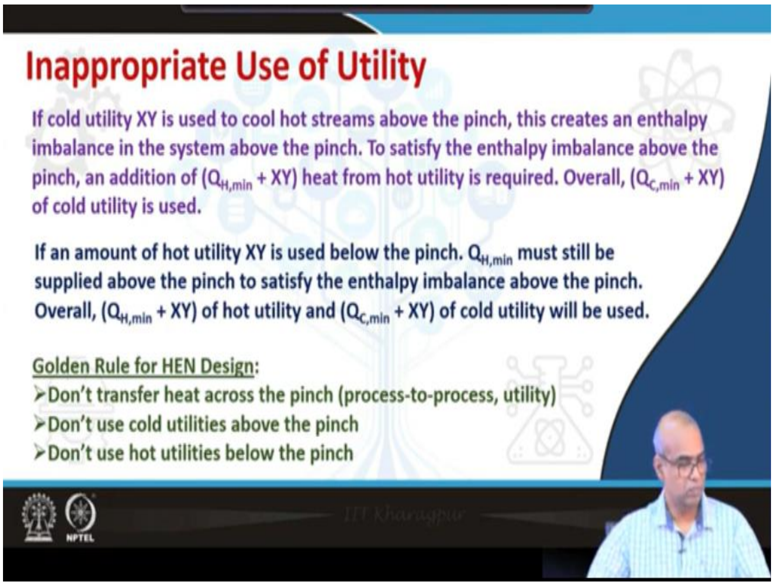

Inappropriate Use of Utility

If cold utility XY is used to cool hot streams above the pinch, this creates an enthalpy imbalance in the system above the pinch. To satisfy the enthalpy imbalance above the pinch, an addition of ($Q_{H,min}$ + XY) heat from hot utility is required. Overall, ($Q_{C,min}$ + XY) of cold utility is used.

If an amount of hot utility XY is used below the pinch. $Q_{H,min}$ must still be supplied above the pinch to satisfy the enthalpy imbalance above the pinch. Overall, ($Q_{H,min}$ + XY) of hot utility and ($Q_{C,min}$ + XY) of cold utility will be used.

Golden Rule for HEN Design:

➢Don't transfer heat across the pinch (process-to-process, utility)
➢Don't use cold utilities above the pinch
➢Don't use hot utilities below the pinch

Also inappropriate use of utility must be avoided. What do you mean by inappropriate use of utility? We should use hot utility above the pinch and you should use cold utility below the pinch. Inappropriate use of utility will be, if I use cold utility above the pinch and hot utility below the pitch. Suppose a cold utility of amount say XY is used to cool hot steams above the pinch.

What will happen, this will create an enthalpy imbalance in the system above the pinch. So to satisfy the enthalpy imbalance above the pinch an addition of QH minimum plus XY heat from hot utility will be required. So accordingly the cold utility will also be increased. Similarly if hot utility XY is used below the pinch note that you will anyway use QH minimum in region above the pinch.

Now, we are using additional XY below the pinch. So you will also use XY cold utility additional amount below the pinch. So the hot utility you are using will be QH minimum plus XY and the cold utility also you will be using QC minimum plus XY. So whether you are using cold utility above the pinch or hot utility below the pinch you basically increase the target for both hot utility and cold utility unnecessarily.

So this gives us the golden rule for heat exchange and network synthesis. So these golden rules for heat exchange and network designs are do not transfer heat across the pinch, either process to process heat or utility heat. Next do not use cold utility above the pinch. And finally, do not use hot utility below the pinch.

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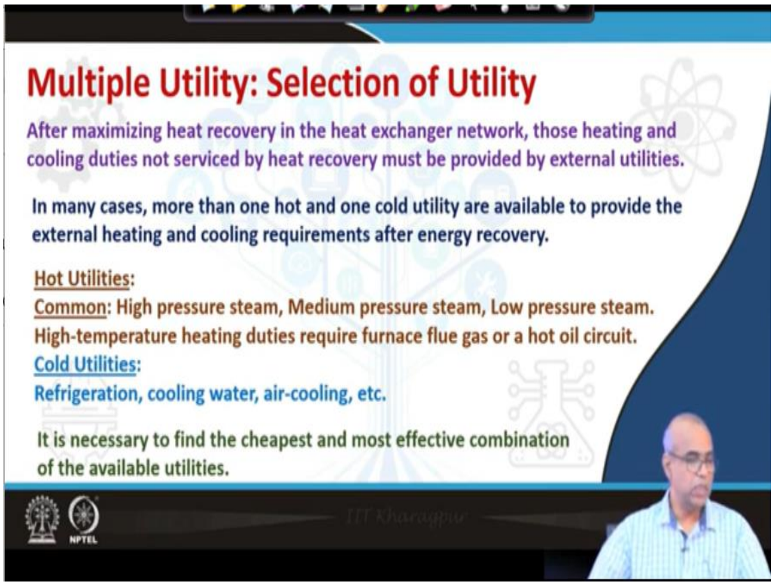

Multiple Utility: Selection of Utility

After maximizing heat recovery in the heat exchanger network, those heating and cooling duties not serviced by heat recovery must be provided by external utilities.

In many cases, more than one hot and one cold utility are available to provide the external heating and cooling requirements after energy recovery.

Hot Utilities:
Common: High pressure steam, Medium pressure steam, Low pressure steam.
High-temperature heating duties require furnace flue gas or a hot oil circuit.
Cold Utilities:
Refrigeration, cooling water, air-cooling, etc.

It is necessary to find the cheapest and most effective combination of the available utilities.

As of now, we have only talked about single utility. Either a single hot utility stream or cold utility, single cold utility source but in many cases there will be several hot utility sources and several cold utility sources. So, how do I select utility? Note that after you have maximized heat recovery in the heat exchanger network those heating and cooling duties which are not serviced by heat recovery must be provided by either external hot utility or external cold utility.

In industry there are several hot utility available, several cold utility available to provides such external heating or external cooling. For example, is very common in an industry to have high pressure steam, medium pressure steam, low pressure steam. And the costs associated with the use of such streams are all different. For example, high pressure steams will always be more expensive than low pressure steam.

High temperature heating duties require furnace flue gas or hot oil circuit. There will be cold utilities at various levels such as refrigeration, cooling water, air cooling etcetera. So definitely we would like to use the less expensive utility as much as possible to minimize the overall cost. So the question now becomes how do I select these utilities? So it is necessary to find the cheapest available utility as well as we may also have to find out what will be the most effective combination of availability.

Because it; may not be possible to service or to provide the entire target by a single source of utility. A single utility may, say a single cold utility may not be enough, a single less expensive cold utility may not be enough to provide for the entire target. So you may have to use a combination of utilities. So may be for the heating purpose, say low pressure steam and may be high pressure stream both I have to use.

So definitely I would like to use as much as possible low pressure steam. But the heat load available with the low pressure steam may not be enough to fulfil that target. So what should be the right combination of this low pressure steam and high pressure steam? So that is the question we need to answer.

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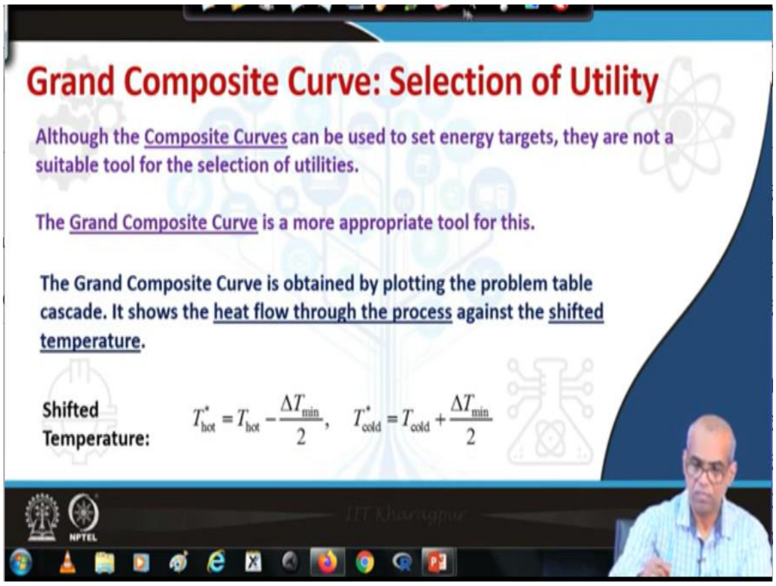

Grand Composite Curve: Selection of Utility

Although the Composite Curves can be used to set energy targets, they are not a suitable tool for the selection of utilities.

The Grand Composite Curve is a more appropriate tool for this.

The Grand Composite Curve is obtained by plotting the problem table cascade. It shows the heat flow through the process against the shifted temperature.

Shifted Temperature: $T^*_{\text{hot}} = T_{\text{hot}} - \frac{\Delta T_{\min}}{2}, \quad T^*_{\text{cold}} = T_{\text{cold}} + \frac{\Delta T_{\min}}{2}$

And the grand composite curve is an appropriate tool to answer this question. The composite curves we have seen that it can tell us about energy targets. But the composite curve cannot tell us about the selection of utility. The grand composite curve will tell us how to select utility. The grand composite curve is obtained by plotting the problem table cascade that you have learnt before.

It shows the heat flow through the process against the shifted temperature. So it is a plot of shifted temperature versus the heat flow through the process. If you remember we have defined the shifted temperature as the temperature of the hot stream minus half of delta T minimum. Similarly, the shifted temperature of the cold steam is the temperature of the cold steam plus half of delta t minimum.

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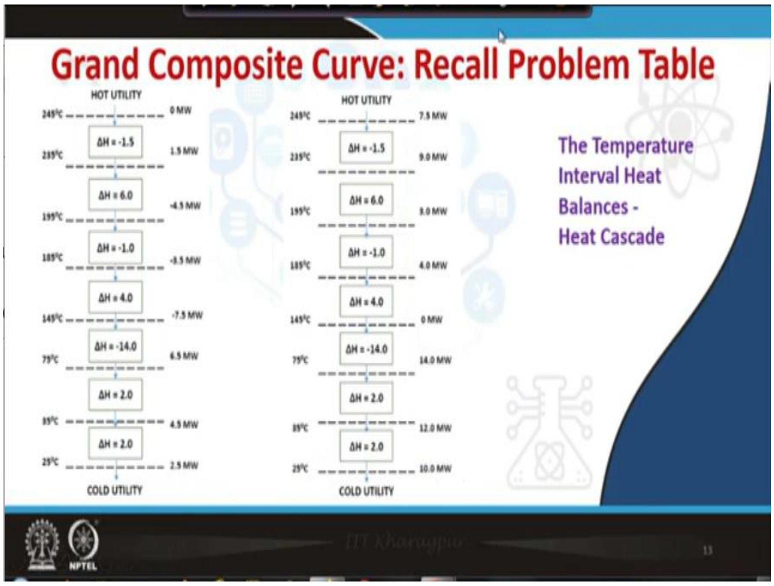

Grand Composite Curve: Recall Problem Table

The Temperature Interval Heat Balances - Heat Cascade

Now, let us recall this problem table. So these heat cascades were prepared after doing the temperature interval heat balance. So, these were the temperature intervals. And at every temperature interval we have done the heat balance. Heat balance was done by finding out the sum of CP values for cold steams minus sum of CP values for hot steams and then this quantity was multiplied by the temperature difference in that interval.

So, I see that also according to our convention delta H negative signifies that there is heat surplus. And delta H is positive means that there heat deficit. So in the first interval we see that delta H is minus 1.5, so there is a surplus heat of 1.5 megawatt. We consider that there is no heat flow from the hot utility at the top of this cascade. Now this 1.5 megawatt that is surplus in the first interval can be cascaded to the second interval.

And there I see that there is a deficit of 6. So when this surplus of 1.5 is cascaded with deficit of 6, what I get is a deficit heat of 4.5 megawatt. Then in the next interval I have a surplus of minus 1, which is cascaded with this minus 4.5 megawatt. So my deficit decreases and this heat value becomes minus 3.5. Next again, there is a deficit of 4. So this value goes to minus 7.5, the sum of this 2, right?

But then in the next interval, I have a deficit of, sorry a surplus of 14, a surplus of 14 megawatt. So when this deficit of minus 7.5 megawatt is cascaded with this surplus of 14, I get 6.5 megawatt of surplus. So this will be cascaded like this down the temperatures scale. And then I see that finally after the end of the computation I get 2.5 megawatt which is be that target for the cold utility.

Now, what we see here that in this table there are both positive and negative heat flows. So, negative heat flow is not possible. So this is a infeasible cascade. So to make it feasible what I do is, I look at the most negative value, which is 7.5, minus. 7.5. So I add 7.5 megawatt from hot utility to the first interval. This will not destroy the heat balance, but this 7.5 megawatt will go to each and every interval down the temperature scale. So now you see this 7.5 will be 0 and all other values will be greater than 0.

So this gives me the hot utility target. This gives me the cold utility target and this is the pinch point. This is the pinch temperature. This is the shifted temperature. So the hot steam pinch temperature will be 145 plus 5 degree Celsius, 150 degrees Celsius. Why 5 degree

Celsius? Because this has been done for delta T minimum equal to 10 degrees Celsius and cold steam pinch temperature will be 145 minus 5 equal to 140 degree Celsius.

Now the grand composite curve is nothing but a plot of this shifted temperature versus this heat flow.

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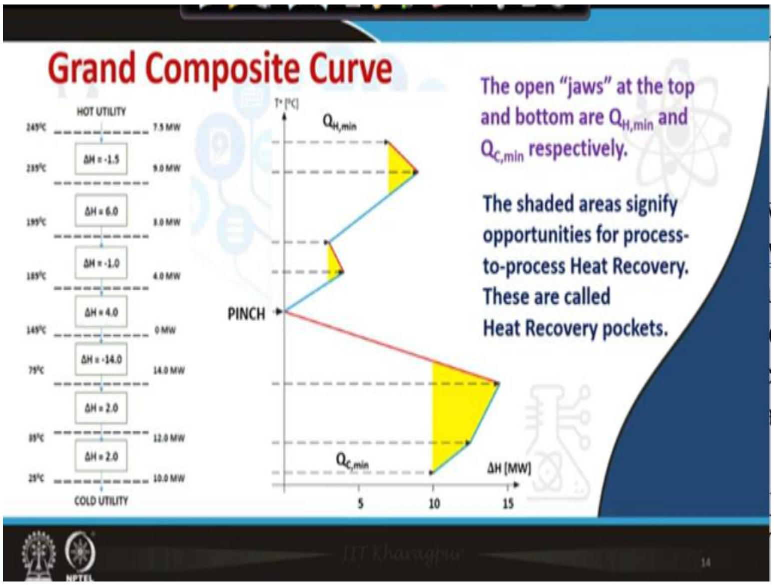

Grand Composite Curve

The open "jaws" at the top and bottom are $Q_{H,min}$ and $Q_{C,min}$ respectively.

The shaded areas signify opportunities for process-to-process Heat Recovery. These are called Heat Recovery pockets.

So at 245 degree Celsius, I have this 7.5 megawatt H value. Similarly, 235 degree Celsius, I have 9 megawatt so on and so forth. So this is how the Grand composite curve can be drawn. This is nothing but a plot of shifted temperature versus heat balance, process temperature versus enthalpy. Now this open jaws at the top and at the bottom indicates the hot utility target and the cold utility target.

Note that these values are nothing but 7.5 megawatt and 10 megawatt. Also the shaded areas signify opportunities for process to process heat recovery. These are called heat recovery pockets, all the shaded regions are called heat recovery pockets.

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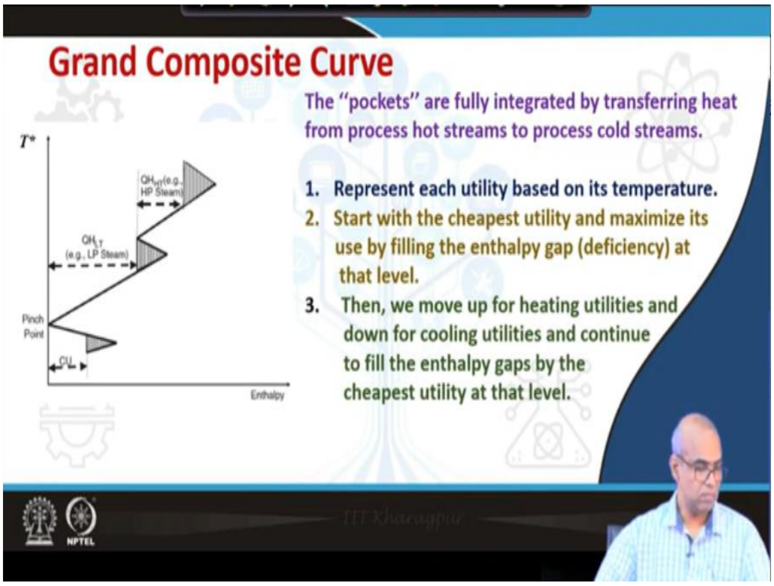

Grand Composite Curve

The "pockets" are fully integrated by transferring heat from process hot streams to process cold streams.

1. Represent each utility based on its temperature.
2. Start with the cheapest utility and maximize its use by filling the enthalpy gap (deficiency) at that level.
3. Then, we move up for heating utilities and down for cooling utilities and continue to fill the enthalpy gaps by the cheapest utility at that level.

These pockets are fully integrated by transferring heat from process hot streams to process cold streams. So now the question comes how do I place utilities? Let us represent each utility based on its temperature. Then start with the cheapest utility and maximize its use by filling the enthalpy gap at that level. So what do you mean by this is? This is the low pressure stream, that means less expensive utility and this is the high pressure stream that means more expensive heat utility.

So they are available at the temperature indicated by this point on the shifted temperature scale. So we start with the cheapest utility and see I maximize its use. I can go up to the point when it will touch the grant composite curve. Then the remaining gap is filled by the more expensive utility. Note that together they cover my hot utility target. The same thing will be done for the cold stream, for the cold utility as well.

So after I, first I will start with the less expensive utility, maximize its use by filling the enthalpy gap or the enthalpy deficiency at that level and then move up for heating utilities or go down for cold utilities. And continue to fill the enthalpy gap by the cheapest utility available at that level.

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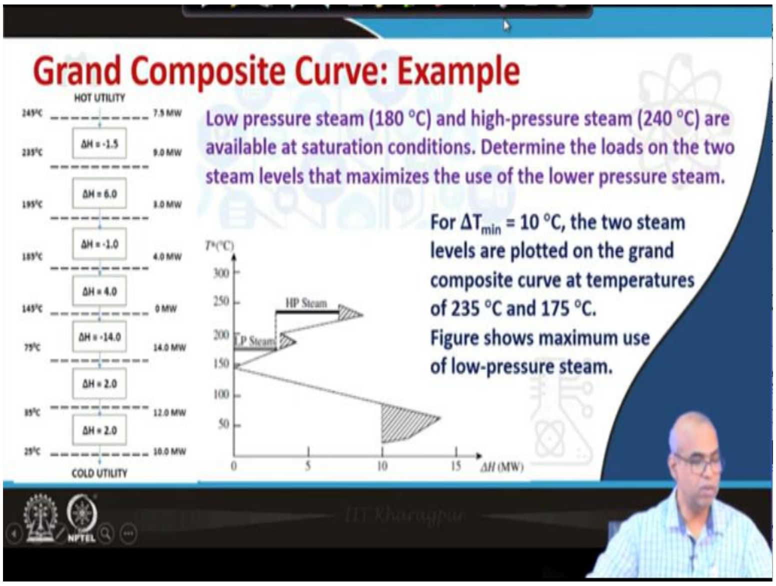

Grand Composite Curve: Example

Low pressure steam (180 °C) and high-pressure steam (240 °C) are available at saturation conditions. Determine the loads on the two steam levels that maximizes the use of the lower pressure steam.

For ΔT_{min} = 10 °C, the two steam levels are plotted on the grand composite curve at temperatures of 235 °C and 175 °C.

Figure shows maximum use of low-pressure steam.

Let us take an example. So low pressure steam, let us say available at 180 degree Celsius, high pressure steam available at 240 degrees Celsius. They are available at saturation conditions. We determine the loads on the 2 steam levels that maximize the use of the low pressure steam. So we are using the same cascade table and make this grand composite curve. Delta T minimum specified is 10 degree Celsius.

So let us plot these 2 steams, hot low pressure steam at 180 degree Celsius and high pressure steam at 240 degree Celsius. So since they are hot stream the shifted temperature will be reduced by 5 degree Celsius because delta T minimum equal to 10 degree Celsius. So I locate them at 175 degree Celsius and 235 degree Celsius on the shifted temperature scale. Now I see, I the less expensive, the low pressure steam.

I use as much as possible that means I go until I touch the composite curve. And then the remaining part I fill up the gap or deficiency with the high pressure steam. So these positions of the low pressure steam and the high pressure steam is important. The position of the low pressure steam tells us that I have maximized the use of low pressure stream. Of course the remaining is to be covered by the high pressure steam.

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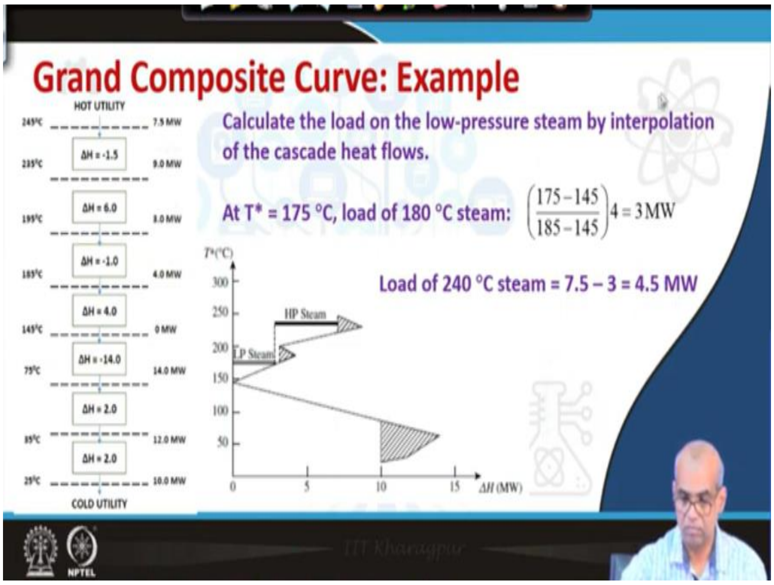

Grand Composite Curve: Example

Calculate the load on the low-pressure steam by interpolation of the cascade heat flows.

At T* = 175 °C, load of 180 °C steam: $\left(\frac{175-145}{185-145}\right)4 = 3\,\text{MW}$

Load of 240 °C steam = 7.5 – 3 = 4.5 MW

So how to calculate the load now? So the load of 180 degree Celsius can be found out by interpolation of the cascade heat flows. Why interpolation is required? Because I have this interval between 185 to 145, but I need between 175 to 145. So I do interpolation. There it was 4 megawatt for 185 to 145 and I find that it is 3 megawatt for 175 to 145. So 3 megawatt is the load for 180 degrees Celsius steam.

So the load of 240 degree Celsius steam will be 7.5, is the total minus 3 megawatt is 4.5 megawatt.

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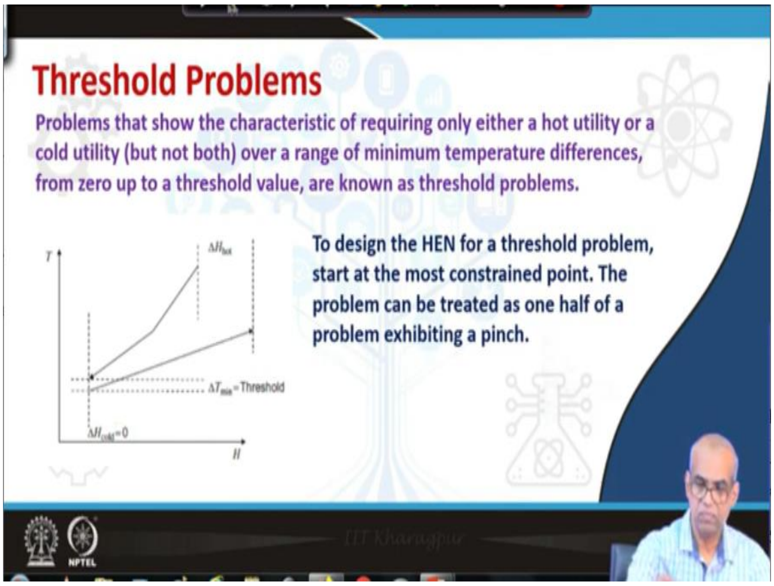

Threshold Problems

Problems that show the characteristic of requiring only either a hot utility or a cold utility (but not both) over a range of minimum temperature differences, from zero up to a threshold value, are known as threshold problems.

To design the HEN for a threshold problem, start at the most constrained point. The problem can be treated as one half of a problem exhibiting a pinch.

The problems that show the characteristic of requiring only either a hot utility or a cold utility but not both over a range of minimum temperature differences from 0 up to a threshold value are known as threshold problems. So there are certain problems where they will be requiring only hot utility or only cold utility but not both and this happens over a range of delta T minimum values.

So it has been plotted for this delta T minimum is the threshold value. So over a range of delta T minimum values, from 0 up to a threshold value, there are certain problems which will use either hot utility or cold utility but not both. Such problems are known as threshold problems. To design heat exchange network for a threshold problem, we start at the most constrained point.

In fact using pinch technology when we start designing heat exchanger network, we start with the pinch point because that is the most constant point. And if you look at these threshold problems, it is something like one half of a problem that shows pinch.

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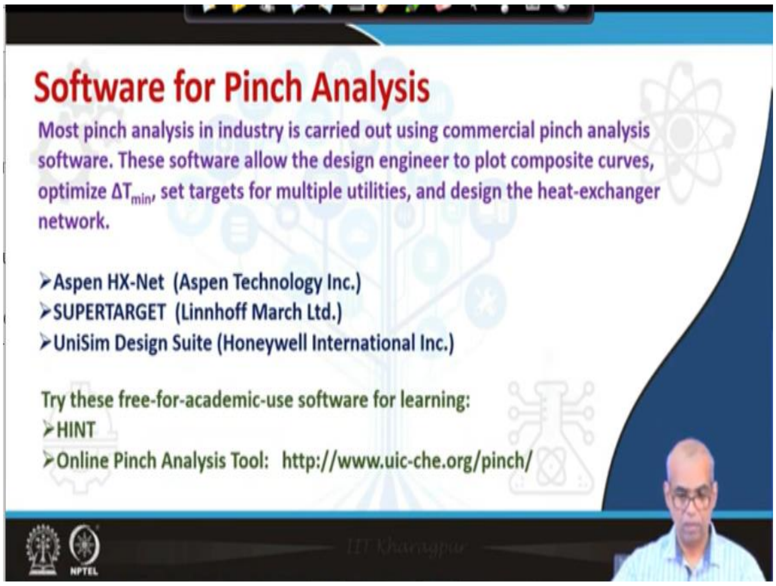

Software for Pinch Analysis

Most pinch analysis in industry is carried out using commercial pinch analysis software. These software allow the design engineer to plot composite curves, optimize ΔT_{min}, set targets for multiple utilities, and design the heat-exchanger network.

- ➢Aspen HX-Net (Aspen Technology Inc.)
- ➢SUPERTARGET (Linnhoff March Ltd.)
- ➢UniSim Design Suite (Honeywell International Inc.)

Try these free-for-academic-use software for learning:

- ➢HINT
- ➢Online Pinch Analysis Tool: http://www.uic-che.org/pinch/

Finally, I would like to mention some of these softwares for pinch analysis. Most pinch analysis in industry will be carried out using commercial pinch analysis software. This software will allow engineers to plot composite curves, optimize delta T minimum, set targets for multiple utilities and also the design the heat exchanger network. Some of the softwares are mentioned here such as Aspen HX-Net for Aspen technology, SUPERTARGET and SUPERTARGET from Linhoff March Limited.

And UniSim Design Suite which is from Honeywell International incorporated. These are all commercial softwares. However, there are some free for academic use software as well. So I suggest that you can make use of either HINT is still available for download. Please look for it over the net or you connect to www.uic-che.org/pinch.

So there is an online pinch analysis tool which is very simple and can be used to do the analysis such as plotting of composite curves, setting up the, determining the targets etcetera and also it does heat exchanger network design.

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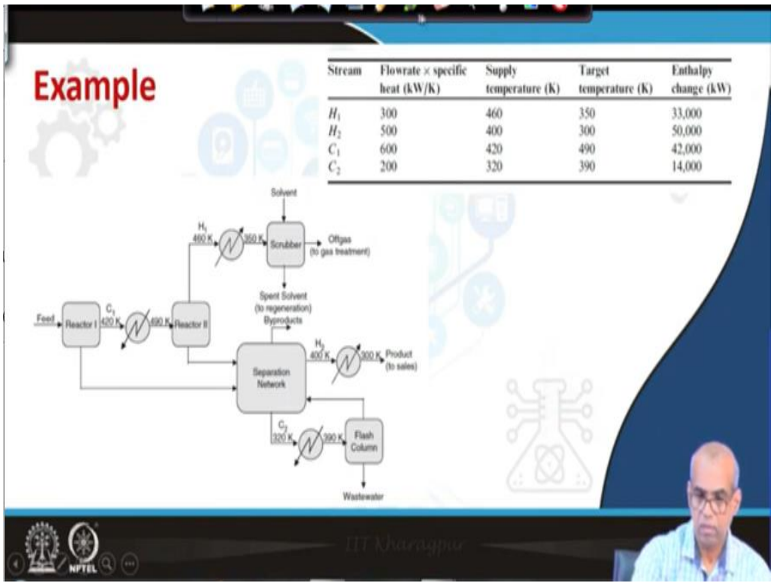

Example

Stream	Flowrate × specific heat (kW/K)	Supply temperature (K)	Target temperature (K)	Enthalpy change (kW)
H_1	300	460	350	33,000
H_2	500	400	300	50,000
C_1	600	420	490	42,000
C_2	200	320	390	14,000

So look at this example. You have a simple process flow sheet with 2 reactors. And then a scar bar as separation network system, flash column etcetera. So you have 2 hot streams and 2 cold streams. So 2 hot streams and 2 cold streams. Their supply temperatures and the target temperatures and the delta H values are given. So if I make use of the online tools

(Video Start Time: 39:12)

To find out the composite curves for this, you just search in the Google; online pinch analysis tool. It will directly take you there or you can also type the URL. Click here to begin. And then you put the source temperature 460, target temperature, 350 and the heat load was 33000. So this was the hot stream then another stream, another hot stream which will be cold from 400 to 300. And it has associated heat load of 50,000.

You have to add the stream data then the first cold stream which needs to be varied up from 420 kelvin to 490 kelvin this as heat load as 42000. This also you add and then finally the last cold stream will be heated up from 320 to 390. And has heat load as 14000. So we have to add it. Now I have added all 4 streams to hot streams to cold streams. Now I proceed with pinch analysis.

It will ask you whether you have saved all your stream data. So now it gives you the stream data that you have loaded, you have just entered. You can also upload the stream data using a textile, data file. Now you note here, you have the delta T minimum as10 degree Celsius. You can change it. Calculate the pinch. So proceed. So this is the pinch you get. For delta T minimum, the pinch temperature is 430 degree Celsius.

Note that this is the plot of enthalpy versus temperature. I can do that. I can also plot T versus H that we have been doing so far. So you clearly see that 60,000 is the cold utility target, 60,000 is the cold utility target. And the heating required is 33000. So this was for delta T minimum 10. So if I increase the delta T minimum, say 20 degree, if I made. So what will happen? The target will increase.

So the cold utility target which was 60,000 soon now increase. So that is as happened. It has now increased to 63,000. So we can do these computations easily. It gives you individual cold composite curve or composite curve as well as the grand composite curve. It also does other work such a steam splitting, steam matching and heat exchanger network. This will be clear when you talked about heat exchanger network in the next class. But you can also work with this software yourself and try to explore.

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So with this we will stop our discussion here.