Process Integration
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Module - 4
Targeting
Lecture - 1
Energy Targeting Procedure

Welcome to lecture series on Process Integration with this lecture I am starting a new module in which is module number four and this is lecture one, and this is on energy targeting procedure. As I have told you, we are going to see a new important feature of process integration.

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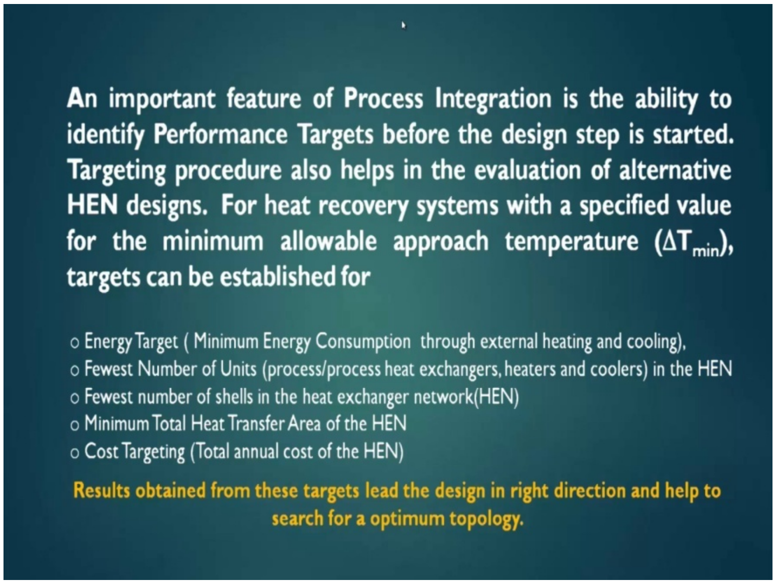

This feature is the ability to identify performance targets before the design type is started. What it means that before designing the HEN I can find out the important parameters or I can say the important target parameters for the design, which has to be achieved through the designed state. This is a new feature of the process integration in the pinch technology or in pinch analysis. Targeting procedure also helps in the evaluation of alternative HEN designs because many designs or many computing designs, which satisfies the constraints of pinch analysis can be developed. Now which HEN design should be accepted? Now the targeting procedure tells us that I should select that design which needs the targets.

Now if you see the targeting procedure there can be many targets, which can be set before the design for a specified value of delta T minimum such targets are energy targets in the energy targets we find out the minimum energy consumption through external heating and cooling for a certain delta T minimum value and when we change this delta T minimum value this energy target also changes because the delta T minimum value affect external heating and external cooling. The second target is fewest number of units pinch analysis also helps to find out before we design what will be the number of units in the heat exchanger network. This number of units include process process heat exchangers heaters and coolers so when we find out the number of units it is a summation of process to process heat exchangers heaters and coolers in the HEN.

In a third targeting procedure we find out the fewest number of shells in the heat exchanger network. That means it will tell that how many number of shells will be present in the total heat exchanger network. Why we have gone for this because the counting of units will not give me that accurate result about the number of units as the shell will be giving because a heat exchanger can be made up of many shells in comparison to one shell and this happens when we are dealing with low f t parameters. A heat exchanger with single shell and heat exchanger with a multiple shell if we compare the cost. The heat exchanger with a double shell the cost will be almost double in comparison to single shell so the number of shells out or number of shells target will give me a better picture about the heat exchanger network. Obviously if we have designed two heat exchanger networks HEN one and HEN two and HEN two has got less number of shells then HEN one one may select HEN two because it has rest number of shells.

Then fourth is minimum total heat transfer area. The heat transfer area of a heat exchanger network gives a fairly accurate estimate of the cost of the heat exchanger network and hence before the design it is always advisable to find out the minimum total heat transfer area as a target. The fifth target is fast targeting through which we can use the heat transfer area target and we can use the energy target so heat transfer area target will provide the fixed cost component of the cost targeting and energy target will give us the operating cost part of the targeting and we can add this two targeting procedure to find out the cost targeting so we have seen that there are quite number of targeting procedures are available with the pinch analysis and these are very important because before design they set the parameters for the design and in the design in general we try to meet these parameters and if we are not able to meet these parameters in the design that means some fault has been carried out in the design or the design has moved to a different path then the path it should move.

Results obtained from this targets leave the design in right direction and help to search for a optimum topology because you have already seen that using the pinch analysis we can design a number of heat exchanger networks or a given problem. If it so then how to find out the optimum or the best heat exchanger network and this targeting procedure help us or lead us or guide us to the optimum topology or optimum design of heat exchanger network so now it must be clear that what is the importance of a targeting procedure. Now will see the first targeting procedure which is energy target and we also know that the energy target can be achieved through the composite hot curves and composite cold curves.

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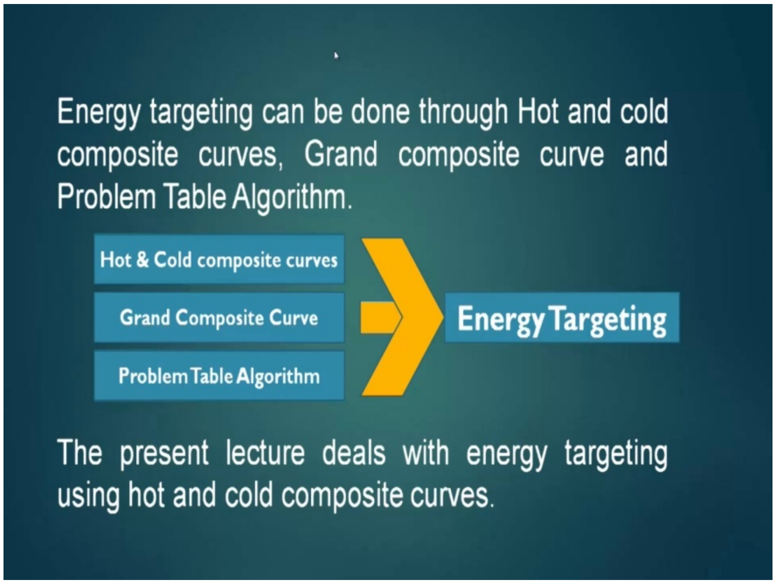

The energy targeting can be done through hot and cold composite curves grand composite curves and problem table algorithm so there are three different methods which are available to you to do the energy targeting hot and cold composite curves then grand composite curves and problem table algorithm. Hot and cold composite curves are a graphical method grand composite curve is also a graphical method with the grand composite curves are derived from hot and cold composite curves or can be derived form a problem table algorithm and the problem table algorithm is a algebraic algorithm to find out what is the energy targeting.

This algebraic algorithm is developed for computer utilization and when more number of cold and hot streams are available in a industry it is generally advisable to go for computer best algorithms and that computer based algorithm is problem table algorithm and we will see this in our subsequent lec's what is actually is a problem table algorithm but at this time you should know that energy targeting can be done either using hot and cold composite curves or grand composite curves or problem table algorithm. The present lec deals with the energy targeting using hot and cold composite curves.

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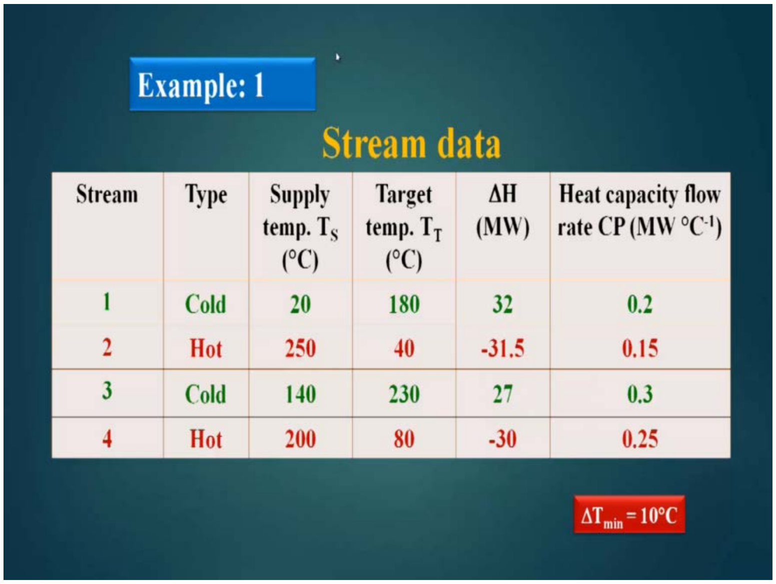

Stream	Type	Supply temp. T_S (°C)	Target temp. T_T (°C)	ΔH (MW)	Heat capacity flow rate CP (MW °C^{-1})
1	Cold	20	180	32	0.2
2	Hot	250	40	-31.5	0.15
3	Cold	140	230	27	0.3
4	Hot	200	80	-30	0.25

Let us explain this with an example so we take a ore stream problem where two cold and two hot process streams are available that supply temperature target temperature that delta H values and heat capacity flow rate are given and the delta T minimum consider for this case is 10 degree centigrade you may ask a question that why 10 degree centigrade why not different values this delta T minimum is a add hock value, which we have selected in this case for 10 degree centigrade’s there are some thumb rules based on, which we assume delta T minimum values to start with but this delta T minimum value can be changed and we can find out the amount of hot utility and cold utility for different delta T minimum values this is possible. And then we also design heat exchanger networks for different delta T minimum values and select a particular delta T minimum value, which we will call delta T minimum optimum at which the heat exchanger network cost is minimum and then the whole network is being operated at that delta T minimum optimum value because the heat transfer the required heat transfer with that particular design operating at a particular delta T minimum optimum value will take minimum cost to transfer the heart.

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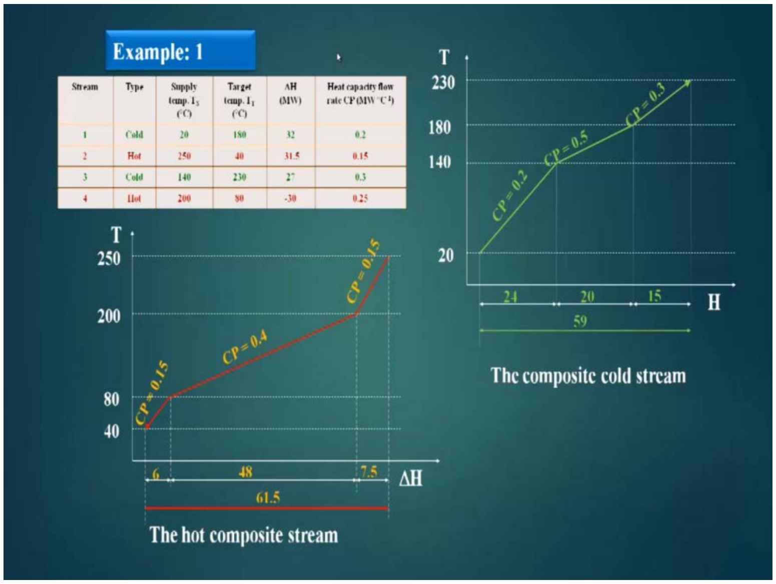

So the first chart is to take the hot streams and three a take composite hot stream and we have created that the hot streams moves from 40 degree centigrade to 250 degree centigrade the composite hot and similarly will also create a composite cold stream and then after making this that is composite hot stream and composite cold streams we will bring them together and will find out what is the value of the hot utility and cold utility.

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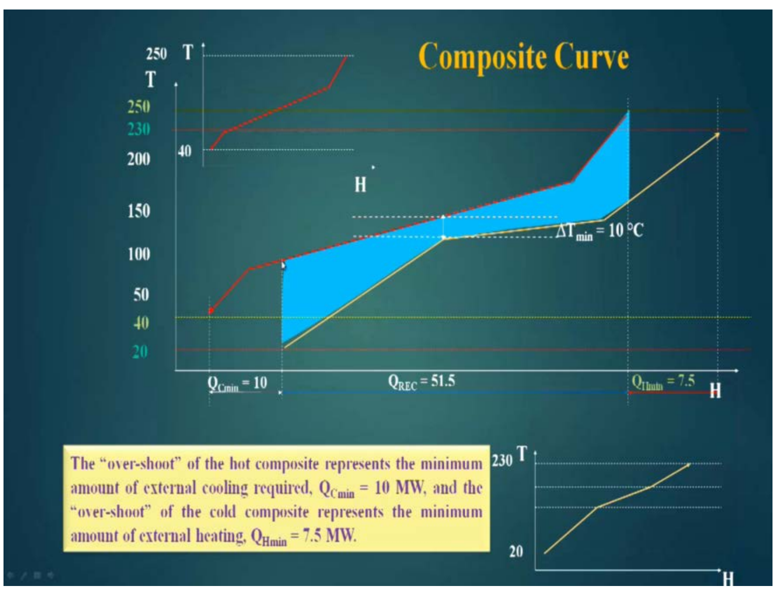

So this is the composite hot stream let us brought here then we go for composite cold streams then we bring to the same graph here so we have put composite hot stream as well as composite cold stream and the delta T minimum is here ten degree centigrade because in the problem we have assume that the delta T minimum is 10 degree centigrade and based on this we will find out the requirement of hot utility as well as cold utility I have already told you that the amount of hot utility and cold utility is a function of delta T minimum so once I fix delta T minimum I also fix the amount of hot utility and cold utility.

So this blue area shows the heat exchange area and when i say heat exchange area this is exchange between process stream to process stream so hot process stream are giving heat to the cold process stream in this area and those area which are not covered here will be heated or can be cold by external means or by external hot utility and cold utility which are either steam or cooling water. So in this problem the external hot utility requirement is seven point 5KW and the external cooling heat demand is 10 and internal heat exchange that is Q recovery is 51.5 and these values that is 10, 51.5 and 7.5 are function of delta T minimum so when I say delta T minimum is equal to 10 degree these three values are fix that is 10, 51.5 and 7.5 the overshoot of the hot composite represents the minimum amount of external cooling required this is Q C minimum this 10MW and the over shoot of the cold composite represents the minimum amount of external heating that is Q H minimum is 7.5 MW.

The physical meaning is that this overshoot is starts from here and goes to here this is the hot composite stream overshoot this composite hot stream may have different number of hot streams it clearly says that those hot streams which are here in the composite will require external cooling to come to this point similarly here the composite cold streams which are here that is there can be a number of different hot streams here and these sorry number of cold streams are here. so this requires external heating to bring from this temperature to this temperature which is equal to seven point five mega watt that means if I pass seven point five mega watt from here then these streams can be heated from this point to this point similarly this hot composite can be cold from this point to this point if I use cold utility worth 10MW.

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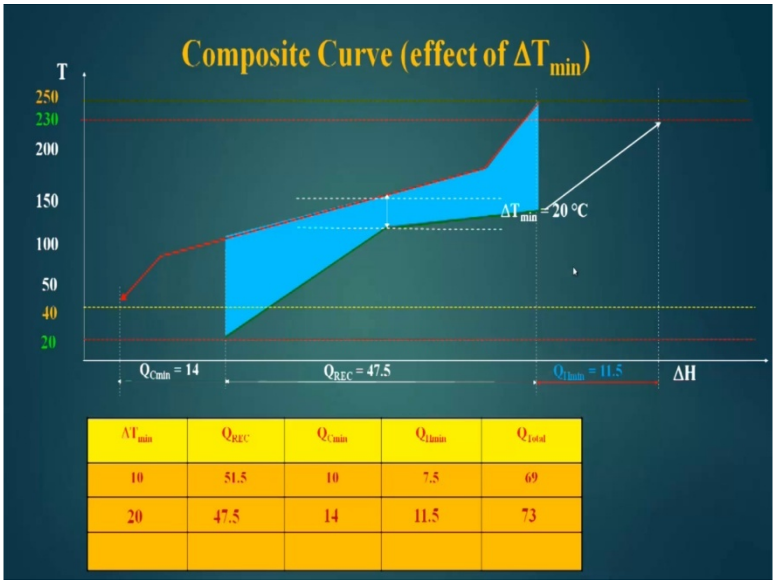

Now let us see what is the effect of delta T minimum we know that if we shift the cold composite curve in the horizontal direction we can change the delta T minimum value and if we change the delta T minimum value the amount of cold utility will change amount of hot utility will change and Q recovery which is the exchange that is this one by this blue area will also change that means from this point to this point this amount will also change so in this case we have made a table for delta T minimum equal to ten we have already seen that Q recovery is 51.5, Q C minimum is 10 and Q H minimum is 7.5 and total heat load that means total heat transacted which is a summation these three quantities is 69.

So my heat transfer area will be a function of Q total because this much of heat has to be passed and my delta T minimum, which is somewhere here, which is 10 degree centigrade will give me this figures 51.5, 10 and 7.5 and total is 69. If I shift this horizontally and make the delta T minimum is equal to 20 degree centigrade then this figures will change. Now I have Q C minimum is 40 Q recovery is 47.5 and Q H minimum is 11.5 that shows that if delta T minimum is increased my hot and cold utility amount is increasing but Q recovery which is exchange to a process to process exchange is decreasing so here we see that for 20 degree centigrade of delta T minimum Q recovery is 47.5, Q C minimum 14, Q H minimum 11.5 and total is 73.

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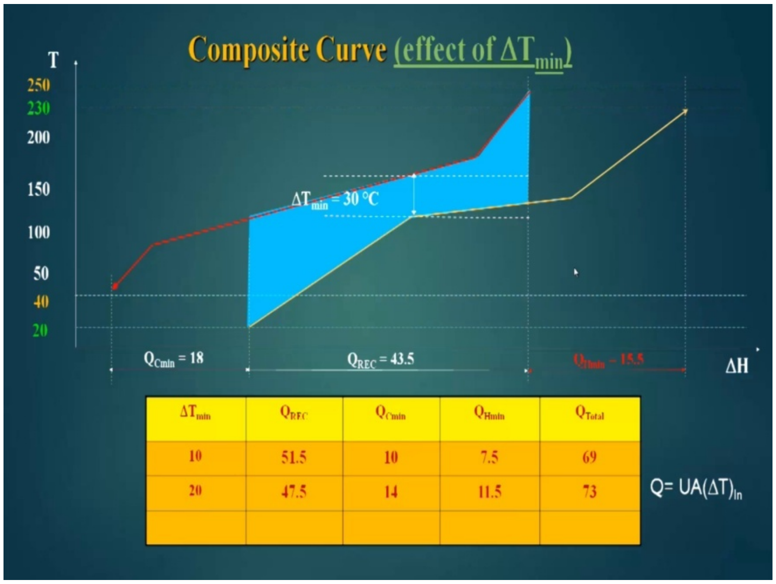

Now we shift for that here the delta T minimum is 30 and this figures again change. Now my Q C minimum is eighteen Q recovery is 43.5 and Q H minimum is 15.5 and the total Q is 77. Now what I understand from this there are two forces which are working here and to analyze this two forces we use the formula which is Q is equal to UA delta T allen now for a fixed Q and for a fixed U if delta T allen increasing a will decrease this we know and when we increase the delta T minimum value basically we are increasing the delta T allen value so for a fixed Q the area will decrease and that’s why we have seen that the fixed cost of a heat exchanger network decreases when we increase the delta T minimum value but what we see here is a different story what we see here that when we are increasing delta T minimum that means we are increasing the driving cost for the heat transfer.

The amount of total heat which needs to be transacted is also increasing at delta T minimum equal to 10 degree centigrade this one 69 at delta T minimum has 20 degree centigrade so 73 delta T minimum at 30 degree centigrade so 77 so this Q is also increasing so when delta T minimum is changing or increasing the Q is also increasing this is a conclusion we made from this that means Q never remains constant when we change delta T minimum and if so happens when delta T minimum is increasing Q is also increasing the benefit which we got by keeping the dealt Q is equal to constant that logic no more holds good and hence the effect of increasing delta T minimum is not so prominent in this case as it has been when Q remains constant.

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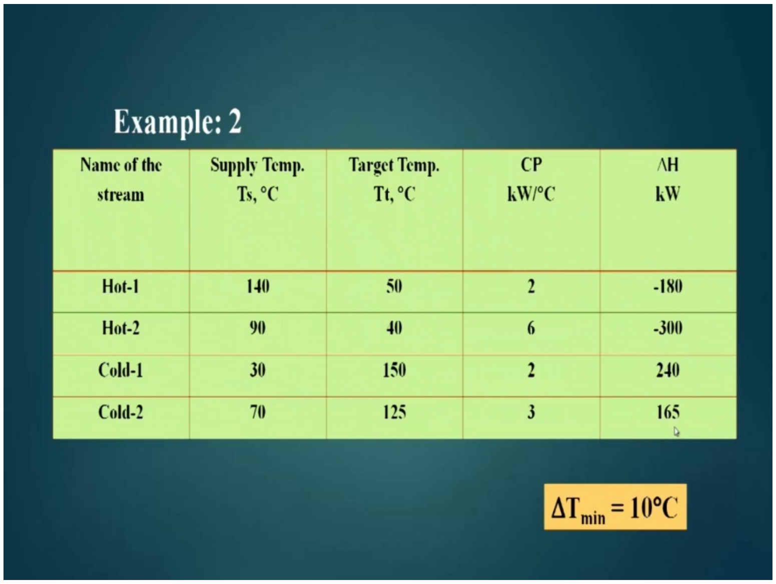

Name of the stream	Supply Temp. Ts, °C	Target Temp. Tt, °C	CP kW/°C	ΔH kW
Hot-1	140	50	2	-180
Hot-2	90	40	6	-300
Cold-1	30	150	2	240
Cold-2	70	125	3	165

So we take second example where there are two hot streams and cold stream and delta T minimum is 10 degree centigrade.

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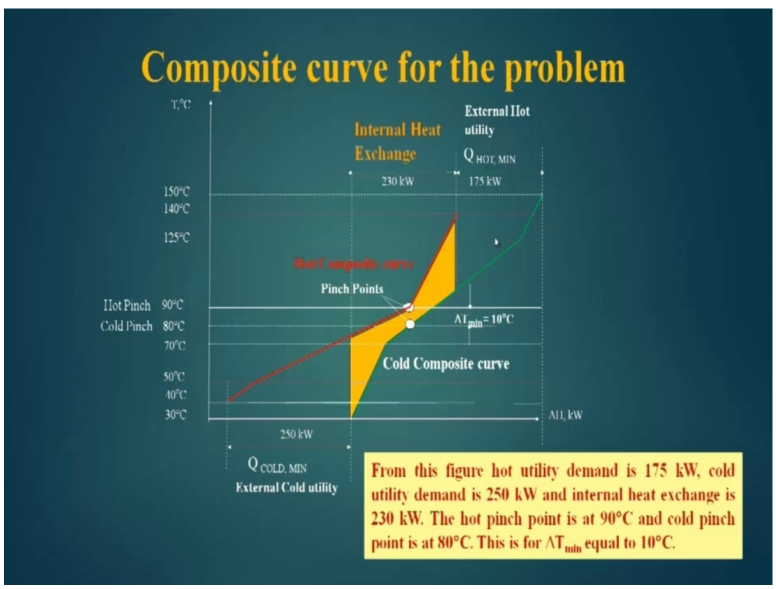

We plot the composite hot we plot the composite cold and here the delta T minimum is 10 degree centigrade. The vertical distance between this point and this point and we get here two pinch point one is hot called hot pinch and another is called cold pinch and many times students are confused when say pinch point it appears to them that it is single point but it is not so this will only happens when the cold composite curve touches the hot composite curve then pinch point this point will overlap over this and I will get a single point but when there is a delta T minimum is specified as in this case 10 degree centigrade it tells that the temperature difference between this point and this point is 10 degree centigrade and hence there is a hot pinch and there is a cold pinch and the difference in temperature between hot pinch and cold pinch is 10 degree centigrade

Now this is the area we shows the internal heat exchange and this is 230kW in this and here it shows Q HOT minimum is 175kW this is a hot external utility and this shows 250kW is Q C cold minimum this is external cold utility now I would like to say that the hot utility and cold utility which you calculate using this energy target are minimum requirement. The pinch analysis does not take about the maximum amount of cold utility or hot utility demand. These are the minimum you cannot go below this if energy consumption principles are to the sustained so it always gives you minimum amount and that’s we write down Q HOT minimum and Q COLD minimum.

So this figure is very clearly tells there are the salient features that 175kW of hot utilities required 200kW of cold utilities required and the heat exchange between process hot stream to the process cold stream is 230kW and the hot pinch as at 90 degree centigrade and the cold pinch is at 80 degree centigrade and all these values are for delta T minimum equal to 10 degree centigrade. If I change the delta T minimum value these values will change that means 175, 250 and 230 and the hot pinch and cold pinch temperature will change.

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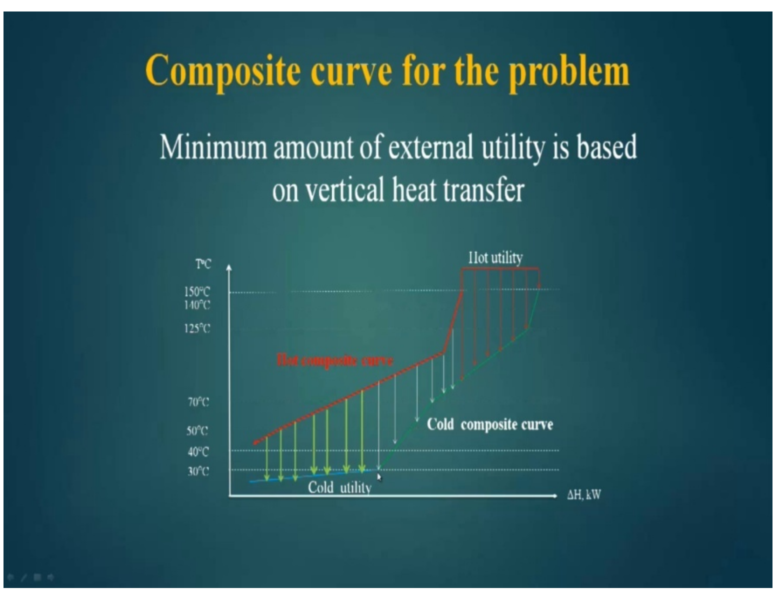

Now when we calculate the minimum amount of external utility this is based on vertical heat transfer that means the requirement this is the hot composite curve and this is the cold composite curve. See this area is filled up vertical lines shows the amount of hot utility so the hot utility which is here passes it vertically to heat the cold streams available from this point to this point this is a cold composite curve. similarly the cold composite curve ends here and this is the for shell of the hot composite curve so this hot composite curve will vertically pass heat to the cold utility which is here so in this case we considered that the utilities are transferring it vertical as well as the process to process heat transfer is also vertically taking place.

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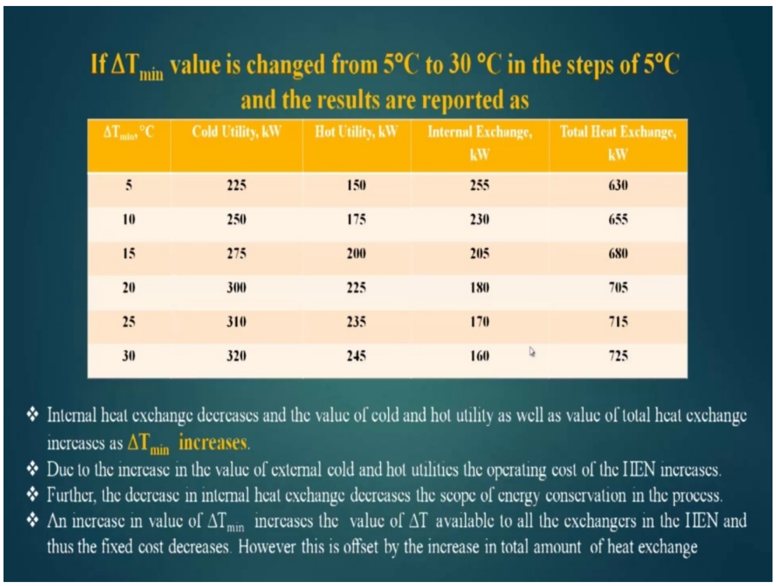

ΔT_{min}, °C	Cold Utility, kW	Hot Utility, kW	Internal Exchange, kW	Total Heat Exchange, kW
5	225	150	255	630
10	250	175	230	655
15	275	200	205	680
20	300	225	180	705
25	310	235	170	715
30	320	245	160	725

Now, if we take that problem and find out what is the amount of cold utility what is the amount of hot utility and what is the amount of internal exchange and what is the total amount then we come to this figures at a this delta T minimum is 5 the cold utility requirement is 225, hot utility requirement is 150, internal heat exchange is 255 and total heat exchange is 630. If you take it to the 50 degree then the same values that is cold utility demand raises from 225 to 275, hot utility amount raises from 150 to 200 and the internal exchange decreases from 255 to 205 and the total increases from the 630 to 680. So here we see that when I am increasing the delta T minimum the cold utility demand is increasing the hot utility demand is increasing and the internal exchange is decreasing and the overall heat exchange is increasing that means if delta T minimum is increase then utility cost will increase whether it is hot utility or it is cold utility and internal heat exchange will decrease.

This is not a good symptom because I have to spend more on utilities cost and the total heat exchange is also increasing that means if I am increasing the delta T minimum a part of it will be nullified by the increasing total heat exchange so the benefit which I get due to the higher driving cost is not that much when Q remains constant. So what conclusion I draw from this is internal heat exchange decreases and the value of cold and hot utility as well as the value of total heat exchange increases as delta T minimum increases.

Due to the increasing the value of external cold and hot utilities the operating cost of the hen increases further the decreasing internal heat exchange decreases the scope of energy conservation in the process. So basically if I want energy conservation in the process I have to maximize the internal heat exchange this is not taking place when delta T minimum is increasing and increasing the value of delta T minimum increases the value of delta T available in all the heat exchanger in the HEN because when I am increasing the delta T minimum all the delta T values of the heat exchangers are on increasing.

Basically in heat exchanger there are two delta T values one in the input side other in the output side if I call them delta T one and delta T two then when i increase delta T minimum this delta T one and delta T two both increase and thus the fix cost decreases because now I am providing more value of delta T minimum and hence area decreases but however as the total heat exchange amount is increasing it will of set have a this is of set by the increasing total amount of heat exchange.

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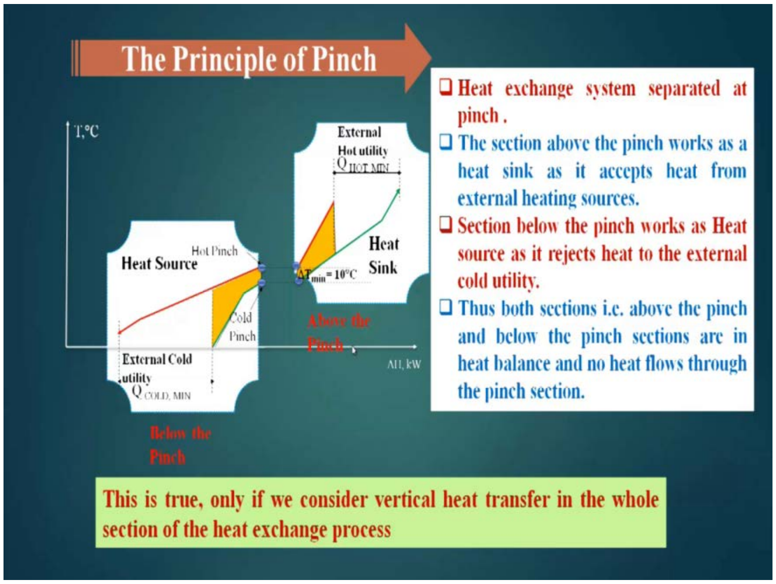

Now will derive some principles of pinch now in the pinch we have seen that in the pinch there is no heat transfer takes place and hence the pinch point divides the problem into two parts and thus I can separate the complete problem into two parts by from the point of pinch now the upper part is called above pinch area and the lower part is called the below pinch area. In the above pinch area external hot utility is required and in the below pinch area external cold utility is required. The section above the pinch works as a heat sink because it accepts heat from the external heat sources, where as the below pinch area rejects heat to the atmosphere and hence it is a heat source that means the below pinch area is always ready to provide heat to the outside world, where as the upper part of the pinch area is always ready to accept it from the outside world and that’s why the upper pinch area is sink and the below pinch area is a heat source.

Both the areas that the upper pinch area and the lower pinch area are under heat balance and no heat flows through the pinch section that upper pinch area the hot streams allow with the external hot utility will transfer the heat to the cold streams and they are in thermal balance that means whatever heat required for the cold stream to heat up from the pinch temperature to this temperature up to this level is fully satisfied by the composite hot here and the external hot utility. Similarly whatever heat available with this composite hot is given to the composite cold as well as to external cold utility so this is also in heat balance and this is also in heat balance and no heat flows from here to here that means across the pinch. This is only true if we consider vertical heat transfer in the whole section of the heat exchange process.

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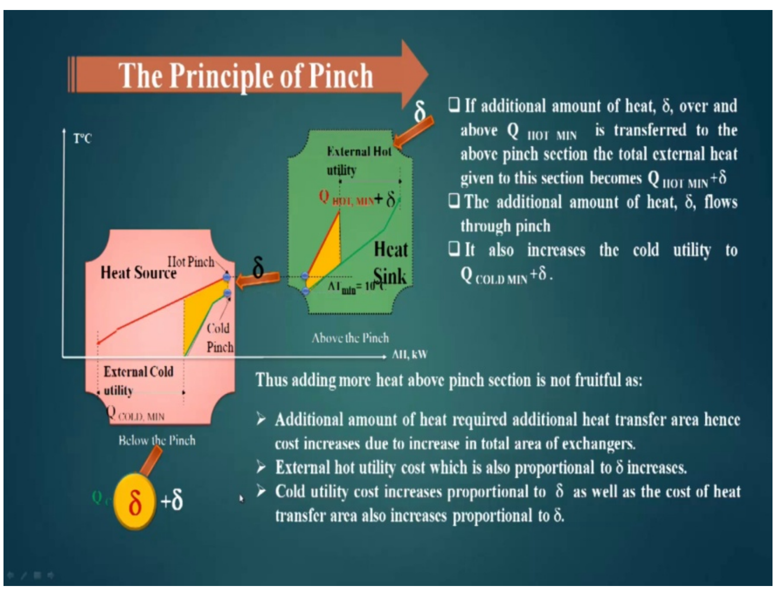

Now, let us see what happens if we put some additional amount of heat equal to delta over and above Q HOT minimum then it is transferred to the above pinch section the total external heat given to this section now becomes Q head hot minimum plus delta that means if I pass on a delta amount of heat to this area then my hot utility amount becomes Q H minimum plus delta. Now when I add more heat to this it is in thermal balance then this amount of heat delta will pass through this pinch and will go to this area. Now here the heat available with the composite hot is in balance will be composite cold and external cold utility so when this extra heat comes here it will increase the external cold utility amount. So the cold utility amount will now become Q C minimum plus delta so in this balanced pinch if I am adding extra heat then it goes through the whole process and glands up into increasing the cold utility amount.

So thus adding more heat above the pinch section is not fruitful because it is not required and if I have forcefully adding the heat then what will happen addition of amount of heat required additional heat transfer area hence cost increases due to increasing total area of the heat exchange when I am adding this delta amount of heat I can add as it is I have provide heat transfer area for this addition so by the heat transfer area require for this above pinch section will increase as well as by the hot utility amount will also increase so the hot utility increase in hot utility amount will increase the operating cost and increase in the area to transfer this delta amount of heat will increase the fixed cost of above the pinch section.

Similarly here also it is increasing the cold utility amount of cold utility by delta amount so the operating cost increase for this and also it will increase the area because I have to provide more area for the coolers to transfer this delta amount of heat. So external hot utility cost which is also proportional to delta increases the cold utility cost increases proportional to delta as well as the cost of heat transfer area also increase proportional to delta by if I am adding a delta value here so goes through this and ends of here.

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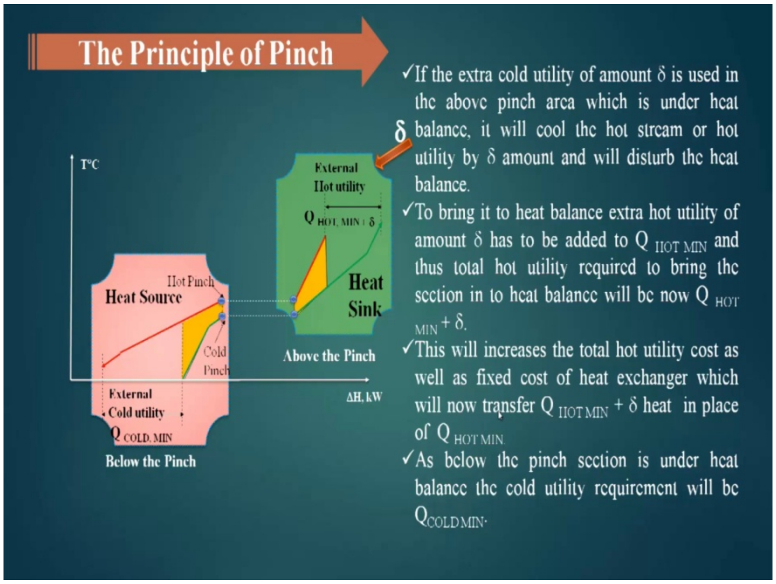

Now let us see that if I add a cold utility at the above pinch area and I add a hot utility into the below pinch area then what happens, if the extra cold utility of amount of delta is used in the above pinch area which is under heat balance it will cool the hot stream or hot utility by delta amount and will disturb the heat balance now if I add a cold utility amount delta here. Then what will happen I have to increase the hot utility by delta m amount to utilize this cold utility so my hot utility amount is increasing to bring it to the heat balance extra hot utility of amount delta has to be added to Q HOT minimum and thus the total hot utility requirement to bring the section to the heat balance will now the Q HOT minimum plus delta now what this will do this will increase the operating cost involved in the above the pinch area this is first thing.

The second thing is that to transfer this cold utility delta I have to provide area and the cost of the cold utility plus to transfer this delta amount which is added to the hot utility that means now my hot utility amount as increased by delta so the operating cost has increased plus to transfer this delta amount of hot utility have to provide again area. So this will increase the total hot utility cost as well as fixed cost of the heat exchanger which will now transfer Q HOT minimum plus delta heat in place of Q HOT minimum. Now in the below as below the pinch section is under heat balance the cold utility requirement will be Q COLD minimum so below pinch the cold utility requirement is Q C minimum that is Q COLD minimum it will not increase but the total cold utility will increase because you have added delta utility at the top.

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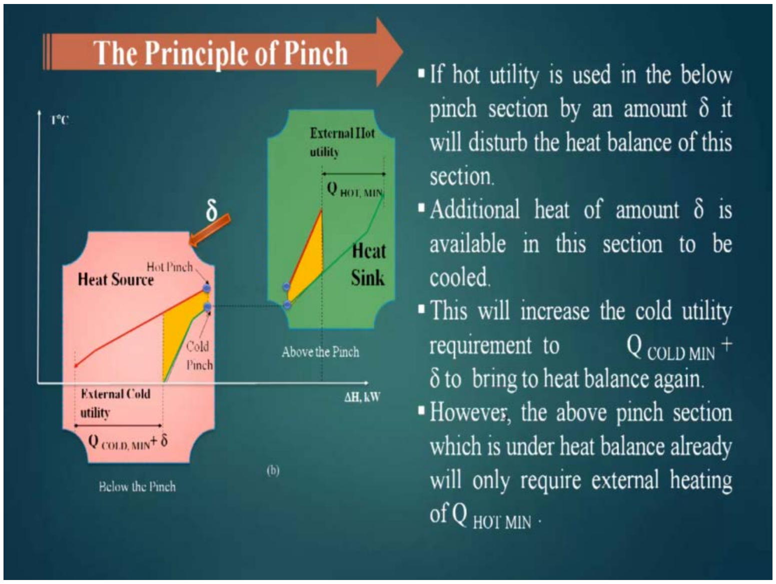

Similarly if I am adding a hot utility to the below pinch area then obviously overall hot utility demand increases and then to nullified this hot utility of delta amount I have to increase my cold utility amount proportionally so my cold utility amount is now Q COLD minimum plus delta. So cold utility amount has increased and total if I see the total picture then hot utility amount has also increase in this case and the area required to transfer this utilities will also increase. However the above pinch section if I see which is under heat balance already will only require external heating of Q HOT minimum the overall hot utility will increase but if I only see the above the pinch area the hot utility amount will not increase for the over problem where as it will increase.

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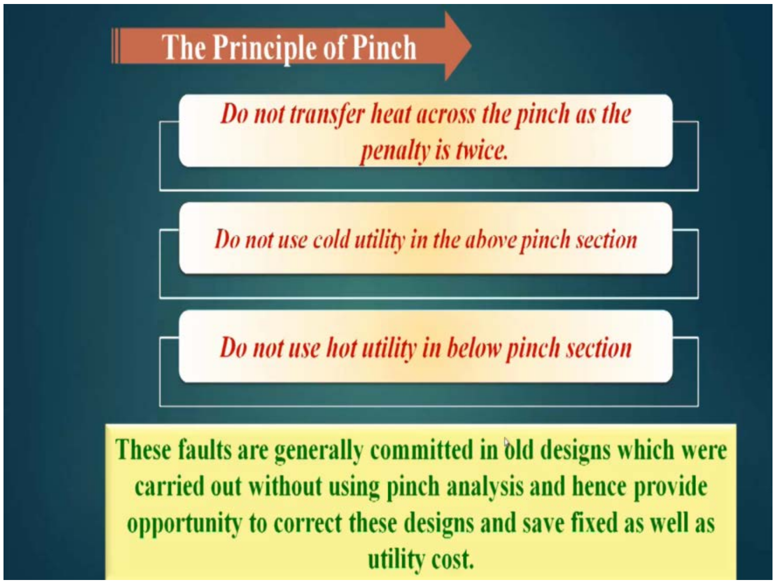

So from this we conclude something what is the conclusion do not transfer heat across the pinch as the penalty is twice because if I transfer heat through the pinch then I pay in terms of area I pay in terms of utility my hot utility increases my cold utility increases and the area required to transfer the extra amount of hot utility and cold utility also increases and that's why the penalty is twice so in the design I see that whatever utility is required I will pass only that much of utility and we will not go for extra utilities, if you see the designs whole designs will see that the if we analyze the whole designs which are there in the industry will find that in many a cases extra heat is being passed then required. And that is why the cost of the heat exchanger network that is operating cost as well as the fixed cost of the heat exchanger network is higher, so by correcting this we can bring down the cost of operation of the heat exchanger network. So it gives a scope to analyze already available heat exchanger networks and to decrease their operating cost when this way pinch saves a lot when it is applied to a existing industry.

The second point is do not use cold utility in the above pinch section we have seen that if you use cold utility in above pinch section the hot utility demand increases, and then the cold utility demand overall cold utility demand also increases and then the area required for this also increases by the amount of increasing cold and hot utility.

The third point is that do not use hot utility in below pinch this also can be argued out in the same manner when we use hot utility below the pinch we increase the cold utility amount and hot utility amount also for the total problem and also more area is required to pass this extra amount of hot and cold utility so this increases unnecessarily the cost of the heat exchanger network. So when will design will keep this in mind that will not pass heat across the pinch will not use any cold utility in the above pinch section and we will not use any hot utility in the below pinch section and if in some existing designs these are found this parts are found we correct them and we can decrease the cost of heat exchanger network as well as the operating cost of the heat exchanger network. These parts are generally committed in old designs which were carried out without using pinch analysis and hence provide opportunity to correct these designs and save fixed as well as utility cost.

Thank you.