**Process Integration**
**Prof. Bikash Mohanty**
**Department of Chemical Engineering**
**Indian Institute of Technology, Roorkee**

**Module - 5**
**Pinch Design Method for HEN Synthesis**
**Lecture - 6**
**Design for Multi Pinch Problems**

Welcome to the lecture series on Process Integration, this is module 5 lecture number 6, the topic of the lecture is Design of Multi Pinch Problems. Based on the pinch rules, we have discussed the design, in the design there are three type of problems we have taken, threshold problems, single pinch problem and multi pinch problem. In the series of design, this is the last lecture, which deals with design of multi pinch problems. The multi pinch problems are different than single pinch problems and they offer considerable challenge in the design of the HEN problems. We will see what are those challengers, and how to overcome down them. Now, when we use multiple utilities then, multiple pinches arise in the design.

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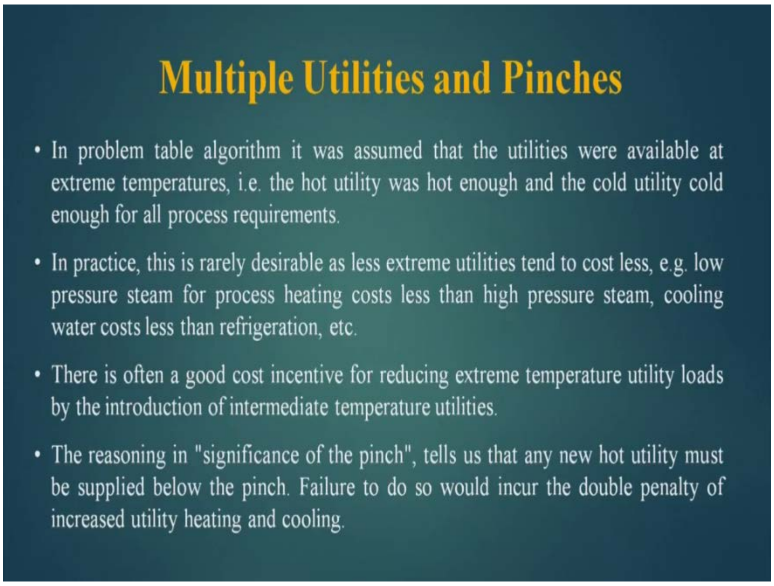


In the problem table algorithm, it was assumed that the utilities were available at the extreme temperatures that means, the temperature of the hot utility will be more than the highest temperature of the stream and the temperature of the cold utility will be lower than the coldest stream available in the process. In practice, this is really desirable, as less extreme utilities tend to cost less and low pressure steam for process heating, cost less than a high pressure steam, cooling water costs less than refrigeration.

Things is clear, it tells very clearly that, the utilities are required at different temperature levels in a design. So, if I replace a low temperature utility by a high temperature utility then, I pay more. Similarly, if I am replacing a lower temperature utility than the cold utility then, I also pay more, that is why selection of proper utility level temperatures is the key to decrease the operating cost of heat exchanger network. There is often a good cost incentive for reducing extreme temperature utility loads by the introduction of intermediate temperature utilities.

And this can be seen very well in GCC when we will talked about fixing of temperature levels of different utilities using a GCC. The reasoning in significance of the pinch tells that, any new hot utility must be supplied below the pinch, failure to do so would incur the double penalty of the increased utility heating and cooling cost. If I divide the HEN into two different parts then, it is very clearly mentioned that, in the upper pinch area, hot utility will be used and in the lower pinch area, cold utility will be used. If I use any cold utility in upper pinch area or hot utility in the lower pinch area then, the penalty will be double.

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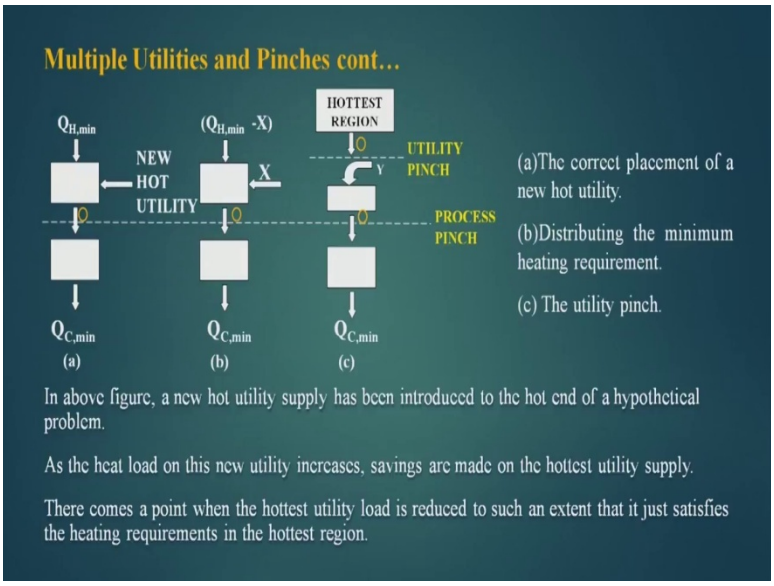


Now, in the figure a part shows that Q H minimum is passed from the top temperature level to the system. And if I have to introduce any new hot utility then, it should be above the process pinch area, it cannot be below the process pinch area. This hot utility has to be injected here, this is the upper pinch area or the hot end, this is the cold end, here I cannot introduce a new utilities. Now, if I am introducing X amount of hot utilities here then, my Q H minimum decreases by X amount, but the total consumption of hot utility is Q H minimum.

But, now utilities are supplied at two temperature different levels, the Q H minimum at some level and X amount of hot utility at a lower level then, the temperature at which Q H minimum minus X is being introduced. Now, this is the hottest region, where I am passing the hot utility and as I am passing the X amount of hot utility, it will create a utility pinch here and the transfer of heat here will be 0. So, the utility pinches are created when we are using multiply utilities.

In the above figure, a new hot utilities supply has been introduce to the hot end of the hypothetical problem. At the heat load on this new utility increases, savings are made on the hottest utility supply, there comes a point when the hottest utility load is reduced to such an extent, it justifies the heating requirement in the hottest region only. That means, will decrease the hottest utility consumption to such a level, that is required for that level only. And if low temperature hot utilities can do the job, we will introduce the low temperature hot utilities.

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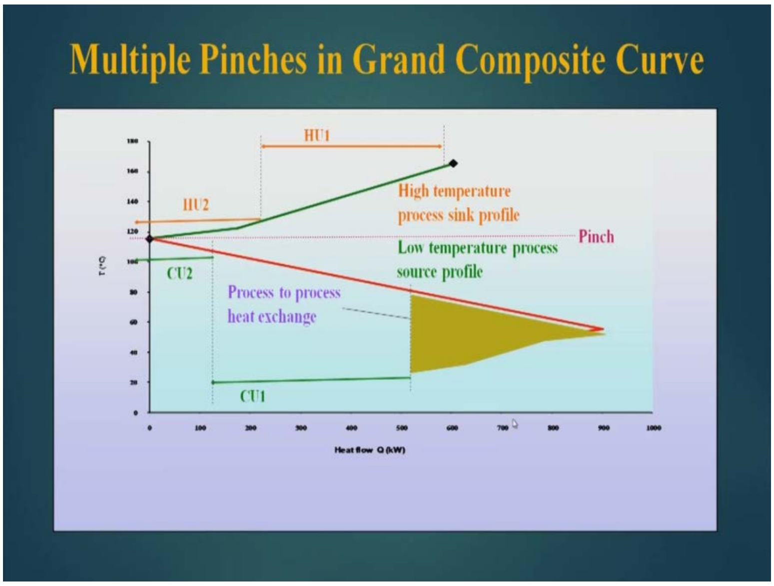

Now, this shows a grand composite curves, this is the pinch point, this is high temperature process sink profile or hot end or upper part of the pinch and this is the lower temperature process source profile and this is process to process heat exchange. Now, why this is called a source profile, because below the pinch, heat is transferred to the surrounding and above the pinch, heat is taken from the surrounding, that is why it is a sink profile and here this is a source profile.

Now, in PTA we assume that, the hot utility is at this temperature level that is, more than this temperature and when we do so then, the delta T is available in this region is very high, which is not required and I am spending a lot on this highest level hot utility. So, what can be done, I can use now two levels of hot utility, one at this level, the other at this level. So, this hot utility level, which is at the highest temperature is giving heat from this stream to this stream and this hot utility is satisfying the heat requirement of streams, which are available in this reason.

So, rather than I am using a single hot utility for the total hot end, we can now break into two hot utilities, one at this level and other one at this level. And doing so, we are decreasing the total cost of hot utility, because the cost of HU 2, which is hot utility 2 will be far less per kiloWatt than the cost of hot utility 1 per kiloWatt cost. Now, similarly, cold utility can also be, different cold utility can also be utilized.

Here, for cooling this stream from this place to this place, this cold utility is utilized that means, the streams which are available from here to here, they are transferring heat to this cold utility, which is CU 1 and stream which are from here to here are transferring heat to the cold utility 2. This way we are able to set the cost of cold utility, because the cost of this cold utility, which is at a higher temperature, will be lower than the cost of this cold utility CU 1 which is at a lower temperature.

So, the conclusion is that, by using multiple hot and cold utility, we can decrease the cost of the cold utility and hot utility. That means the consumption cost of the hot utility and the consumption cost or operating cost of the hot and cold utilities. Now, to give an example that, how multiple utilities are accommodated and once we accommodates multiply utilities, we will get multiple pinch.

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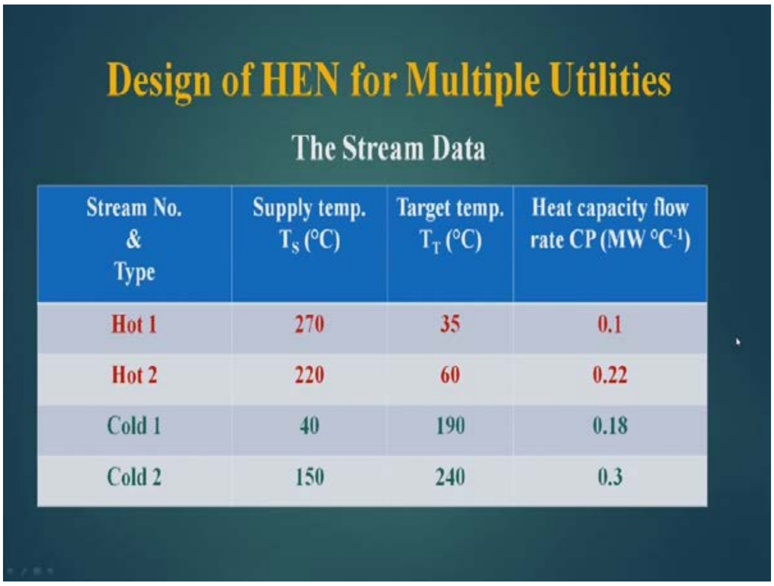


| Stream No. & Type | Supply temp. $T_S$ (°C) | Target temp. $T_T$ (°C) | Heat capacity flow rate CP (MW °C$^{-1}$) |
|---|---|---|---|
| Hot 1 | 270 | 35 | 0.1 |
| Hot 2 | 220 | 60 | 0.22 |
| Cold 1 | 40 | 190 | 0.18 |
| Cold 2 | 150 | 240 | 0.3 |

Then a problem where multiple pinches occur, how we design the heat exchanger network, for that purpose, the stream data of this table is taken, there are two hot streams and two cold streams.

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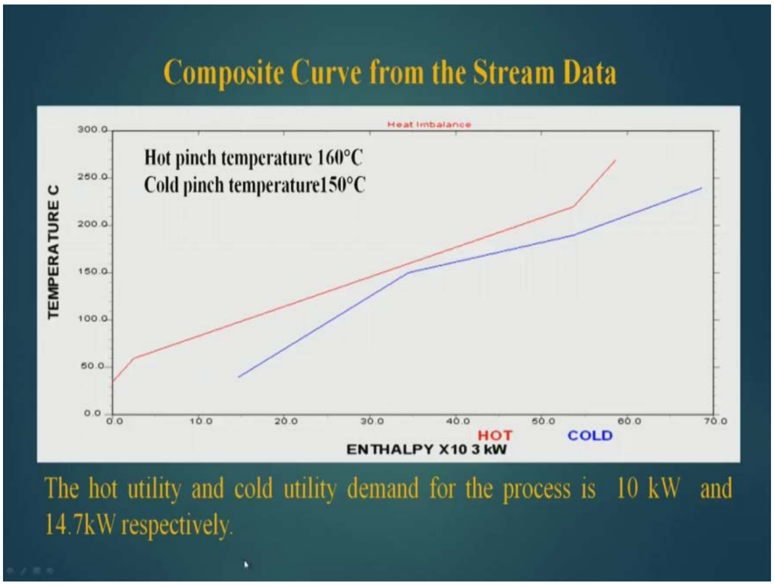


Now, this shows the composite curves of the stream data available, hot pinch temperature is at 160 degree Centigrade and cold pinch temperature is 150 degree Centigrade, delta T being 10 degree Centigrade. Now, if we do the P T of this then, the hot utility and cold utility demands for the processes are 10 kiloWatt and 14.7 kiloWatt respectively. Now, this is a result from the energy targeting and why we are providing this region, because through the design, we have to achieve these results, the hot utility demand and the cold utility demand. If it is achieved in a MER design then, we should be happy, but not in all times we can achieve the minimum hot utility and cold utility demand. In some design it may increase, but at a design which achieves, this is consider to be a better design.

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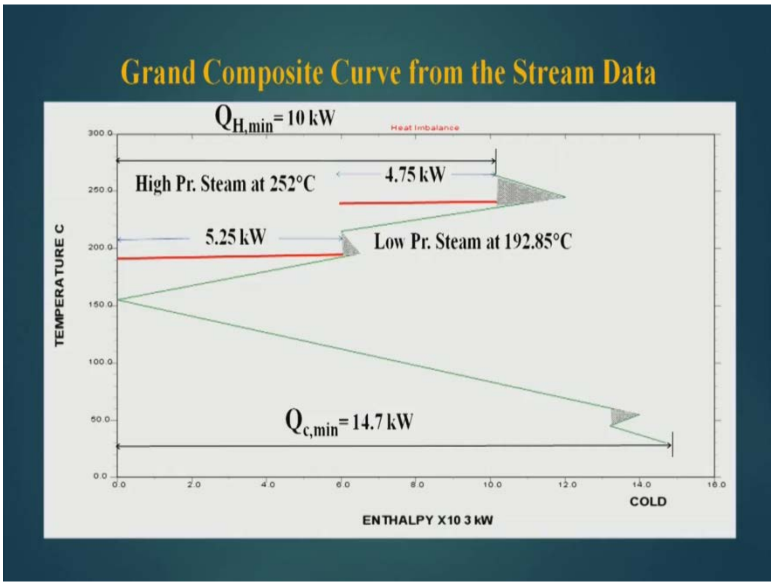


Now, if I plot the GCC of this then, the GCC would looks like, here their pockets are process to process heat transfer. So, I can fix up a hot utility from here to here, which gives me 10 kilowatt and here, I am putting up the hot utility at the highest temperatures. Similarly, the cold utility demand which is Q C minimum is 14.7 kiloWatt and this is distance from here to here. Now, to supply this amount of hot utility, I can supply this in two temperature levels, I can use high pressure steam at 252 degree Centigrade.

And this only heat this portion of the GCC, because heating from this to this is required, this stream from this point to this point is heated up by the hot stream from here to here, so this is a process to process heat transfer package. So, from here to here this point, I have to heat the streams using the high pressure steam, for this part we will be using low pressure steam, from heating from this point to this point. So, low pressure steam is at 192.85 degree Centigrade, now the quantity of high pressure steam required is 4.75 and the quantity of low pressure steam required is 5.25.

Now, we see earlier, we have to use 10 kilowatt of high pressure steam to heat the upper part of the pinch. Now, we are only using 4.7 kiloWatt of high pressure steam at this level, this is not at this level, because the heating is not required at this level. So, now the high pressure steam at this temperature level has been substituted by two heating utilities, one at 252 degree Centigrade and other at 192.85 degree Centigrade. The amounts will be 4.75 kiloWatt and 5.25 kiloWatt. Now, doing so what we gain, we are able to reduce the operating cost of the HEN by decreasing the cost of the hot utility consumption.

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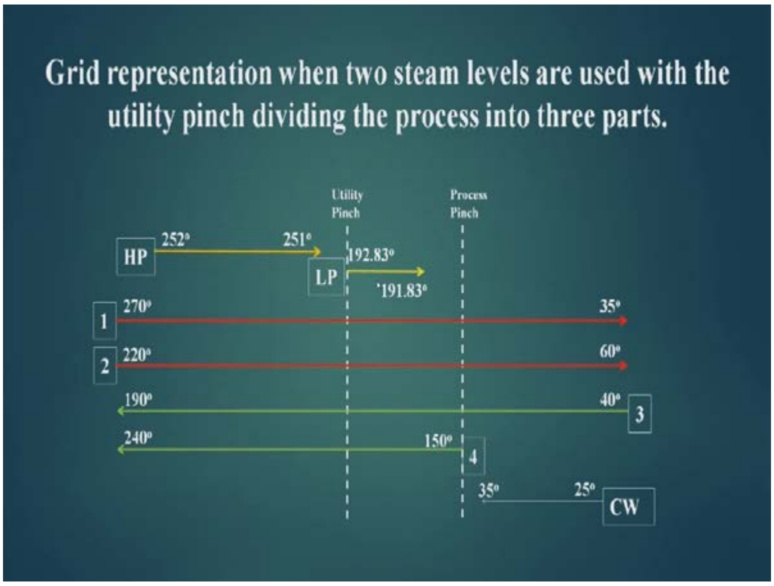


Now here, this is the grid diagram, we have two process streams, hot 1, hot 2 and this is cold 1 and cold 2. And then, we are using cooling water as cold utility, which is from 25 degree Centigrade to 35 degree Centigrade. And then, we are using two hot utilities, one HP stream, high pressure stream for 252 degree Centigrade to 251 degree Centigrade and LP stream from 192.83 degree Centigrade to 191.83 degree Centigrade. It need some discussion, now when we take some hot utility, which is condensing type that means, it passes latent heat of polarization.

We assume that the temperature of this is decrease by 1 degree centigrade why, because a condensing steam or a boiling steam has got CP values, which is equal to infinite. And if we considered to be CP to be infinite, obviously it will create a lot of problem in calculation and that is why, we decrease the temperature by 1 degree centigrade, so that we get a finite value of CP, which is not infinite. As this is in heat balance, so the value of CP which is being calculated, satisfies the amount of heat, which a particular hot utility will give.

So, we are not committing any mistake as far as calculation is concerned, now let us see the physical aspect of this. Now, when in a heat exchanger a condensing steam is used then, the condensing steam will travel from one end of the heat exchanger to other end of the heat exchanger, for heating that tubes from outside say. Now, this transfer of the steam from one end to the other end will only be done, if there is a pressure differential. That means, at both the ends, the pressure of the steam is different and if the pressure of the steam is different then, the temperature will also be different.

So, practically also, we will have two different types of temperatures, at the inlet end of the stream and at the exit end of the stream. So, if I am assuming that, there is a change in temperature of this stream, that is not incorrect and for the computation also, this is been assumed. In practically, it may not decrease by 1 degree Centigrade, it may decrease by 0.8 degree Centigrade or 0.7 degree Centigrade, but there will be a decrease. And when I am assuming this, I am calculating a CP values, who is satisfy my heat supply and that is why in the calculation, it will not introduce any error.

Similarly, here I assume that my cooling water is from 25 degree Centigrade to 35 degree Centigrade. This is also a assumptions, because cooling water are not used or cooling water is not used beyond 40 degree Centigrade. This is a design rule, because there are inwards soluble salts present in the cooling water and after 40 degree Centigrade, there is a deposition of salt on the hot surfaces and it will increase falling phenomena.

And hence, for the safety reasons, we have taken this temperature from 25 to 35 degree Centigrade, 25 degree centigrade which is the lowest temperature will be decided by the climate conditions. In the winter, it may decrease to say 10 to 20 degree Centigrade in the northern part of India and the summer, it may raised to say 30 degree Centigrade also.

So, depending upon the situation, environmental condition, this temperature will be taken, but this is true that, it should not go beyond 40 degree centigrade, otherwise a lot of falling will takes place in the cooling equipment and we have to use some salts to suppress them. So, here we have used the hot utility and cold utilities also, so at the LP end, we get a utility pinch and there is a process pinch. So, in this problem, there are two pinches are available, one process pinch and other is utility pinch.

And both the pinches, the heat flow is 0 that means, now this problem is divided into three parts, above process pinch, second part is between utility pinch and process pinch, and third part is below utility pinch. So, the introduction of utility pinch is further dividing the problem and here, we have problem in three parts and they have to be tackled differently or separately. That means, we will design this part, we will design this part separately, we will design this part separately and then, we joint to form the total heat exchanger network.

No heat flows from this part to ((Refer Time: 24:43)) this part, no heat flows from this part to this part or this part to this part. So, the addition of utility pinch, which is due to the addition of multiple hot utility is creating utility pinch and utility pinch further divides the problem. Process pinches divide the problem into two parts and when we are using utility pinch then, this part was further divided into two parts.

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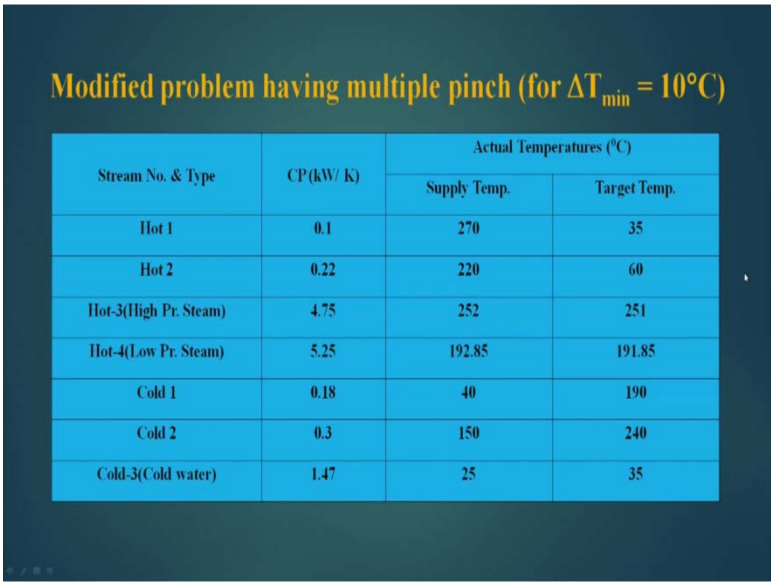


| Stream No. & Type | CP (kW/ K) | Actual Temperatures (°C) | |
|---|---|---|---|
| | | Supply Temp. | Target Temp. |
| Hot 1 | 0.1 | 270 | 35 |
| Hot 2 | 0.22 | 220 | 60 |
| Hot-3(High Pr. Steam) | 4.75 | 252 | 251 |
| Hot-4(Low Pr. Steam) | 5.25 | 192.85 | 191.85 |
| Cold 1 | 0.18 | 40 | 190 |
| Cold 2 | 0.3 | 150 | 240 |
| Cold-3(Cold water) | 1.47 | 25 | 35 |

Now, our modified problem when we introduced the hot utilities, and cold utilities this, only in this table hot utility and cold utilities are introduced. So, this is a balanced, I should say there is a balance stream table and delta T minimum is 10 degree Centigrade for this purpose, the CP value comes out to be 4.75 here and the CP value of cold low pressure steam is 5.25, where the difference is 1 here.

M C P is equal to Q, so this has come as the delta H of this stream, which is 4.75 and this is delta H of low pressure steam, which is 5.25. And this cold CP is computed from the cold utility 35 minus 25 into CP is equal to the amount of the cold utility and from there, we can calculate this value of the CP of cold water as 1.47.

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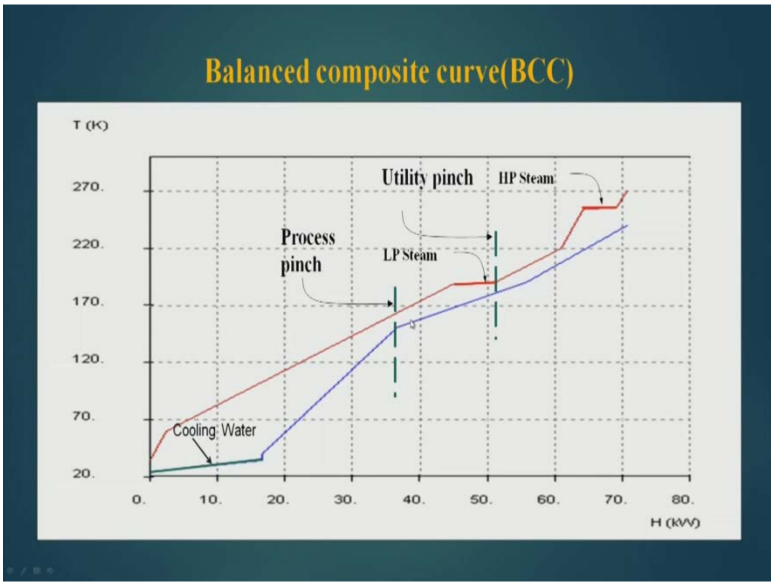


Now, when we plot the balanced composite curve and this we have discussed a lot, a balance composite curves is generated when utilities are added to this stream table. So, here we see that, we have added cooling water here, so this is a cold utility and here two hot utilities are added. Basically, when you are adding this, this part of the curve which was earlier here, is being shifted by this amount. Similarly, this part was here earlier, it is being shifted by this amount when we are adding hot utilities.

So, this is my process pinch, this is my utility pinch and this is HP stream from here to here and this is LP stream from here to here. So, this is how, a balanced composite curves will look like and this will be created when we add cold utilities and hot utilities. Basically, it is shifting the remaining part of the curve to this amount and this is shifting the reaming part, this was the remaining part, by this amount in the enthalpy axis.

So now, this part will be designed separately, this part will be designed separately and this part will be designed separately. No heat flows from this part to ((Refer Time: 28:33)) this part or this part to this part, no heat flows from this part to this part and this part to this part.

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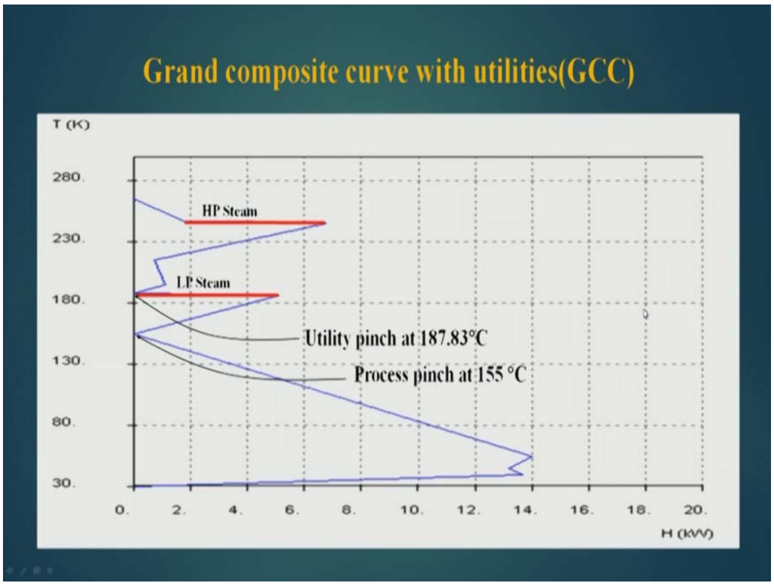


Now, if I am plotting a GCC of the balanced composite curve, this is the GCC, here I am using hot stream, here I am using LP stream, here we see that is a pinch point, which is called utility pinch and this is the process pinch. This is the process pinch, this is the utility pinch and this is the cold utility, this is utility at 187.83 degree Centigrade, this is process pinch at 155 degree Centigrade, these are the shifted temperature obviously.

Now, having been defined the multi pinch problem and it is nature, why a multi pinch problem is generated. Now, let us see how to design a multi pinch problem that means, how to design a heat exchanger network for the multi pinch problem. So obviously, pinch design rules have to be followed.

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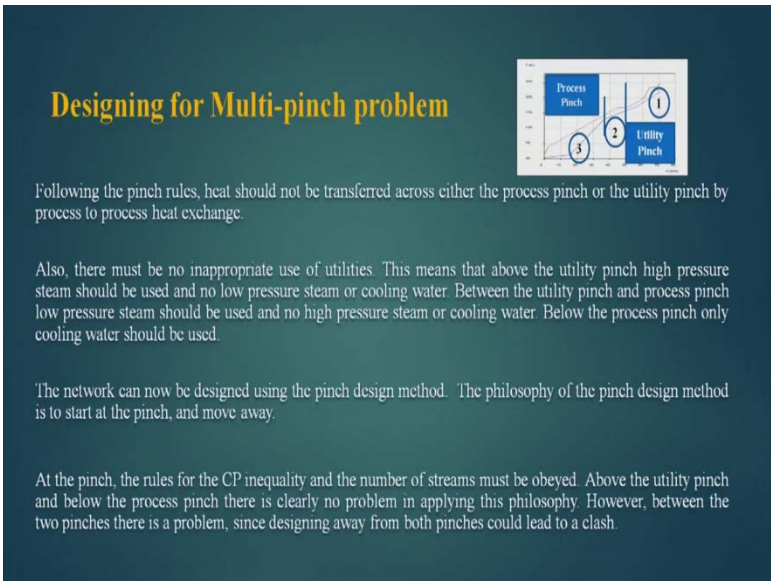


Now, the pinch designed rules tells that, heat should not be transferred across the, either the process pinch or the utility pinch by process to process heat exchanger. So, we will remember that, no heat will transferred through, either process pinch or utility pinch. Also, there must be no inappropriate use of utility, what is it mean, this means that, above the utility pinch which is this region, this is above the utility pinch, because this is the utility pinch and this is the process pinch, this line denotes.

So, above the utility pinch, high pressure steam should be used and we are using high pressure steam above the utility pinch and no low pressure steam or cooling water should be used that means, in this region, no low pressure steams or cold water should be used. Between this utility pinch and process pinch, which is the area between these two lines, low pressure steam should be used and we are using low pressure steam here and no high pressure stream or cooling water should be used, this has to be remembered.

The third is, below the process pinch, only cooling water should be used that means, this area is below the process pinch, because process pinch is this line, so below this area, only cold water should be used. The network can now be designed using the pinch design methods, the philosophy of the pinch design method is to start at the pinch and move away. So, this we have already advocated this principle and why this is necessary, we have already discussed.

So, here also the same philosophy will be used that means, we will start at the pinch and will move away from the pinch. Now, at the pinch rules for the CP inequality at the pinch, the rules for CP inequality and the number of streams must be obeyed. Above the utility pinch and below the process pinch, there is clearly no problem in this region. And in this region, there is no conflict in applying CP rules or the number of streams rules. But, the area this is somewhat confusing that means, between the two pinches, however between the two pinches there is a problem, since designing away from both the pinches, could lead to a clash, why this we will explain.

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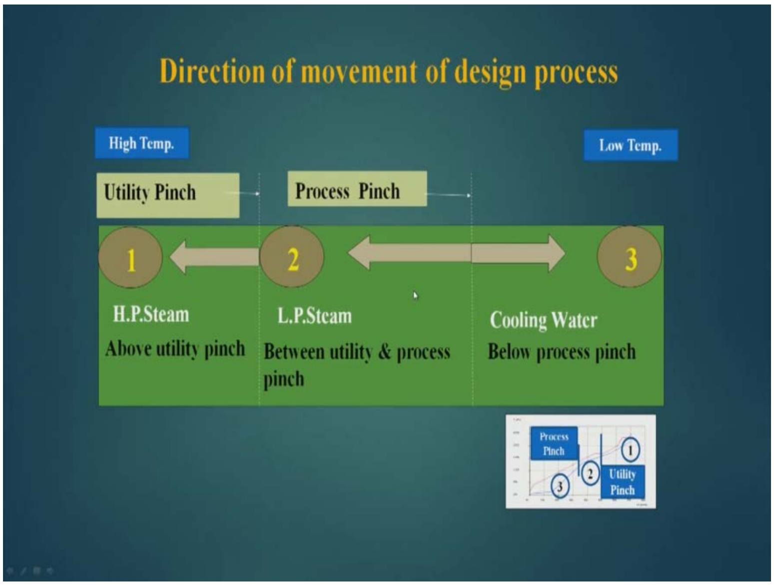


Now, below the process pinch, no problem, this is uni directional design, but if I consider process pinch then, my design should start from here and this move away in this direction and in this direction, it should start at process pinch and move way upto this. Above the utility pinch, the direction is the same direction, I have no problem, but between these two pinches, if I consider this pinch to start my design from this pinch, the direction of design is this.

If I consider this pinch as my pinch for designing then, the direction will be this, so there is a clash in direction in this area, the rules says that, you can design in this direction also and you can also design in this direction. Now, the question is that, which pinch is more constricted if I can define this, at which pinch is more constricted or I can find out through arguments. Then, I will start my design from that pinch and then, the ambiguity will disappeared or the confusion regarding the direction of the design will disappear.

Now, here while we will be using HP stream in this between process pinch and utility pinch, I will be using LP stream and here cooling water, so no confusion as far as the utility is to be used. Now, as far as the direction of the design is concerned, there is a confusion, that where to take the utility pinch as the starting point of the design or to take the process pinch as the starting point of the design, it takes further clarification.

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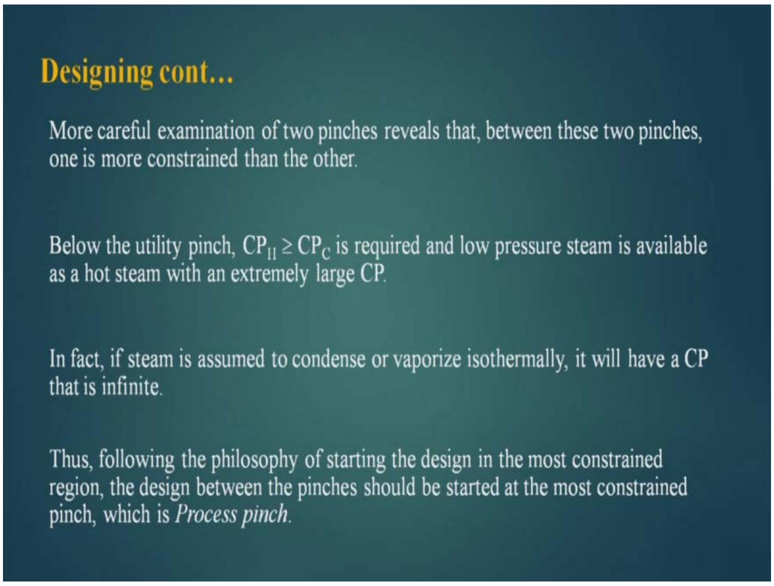


The more careful examination of the two pinches reveal that, between these two pinches, one is more constrained than the other. This is what we are searching, that which pinch is more constrained, utility pinch or process pinch. And the pinch tells that, where the problem is most constrained, you start design from that point. So, here we have to find out, which pinch is utility pinch or process pinch is most constrained. Now, let us see the arguments, below the utility pinch, C P H should be greater or equal to C P C, this requirement is there and you have to satisfy this requirement for placing matches.

We see here, the low pressure steam is available as the hot stream below the utility pinch and which has got a extremely high value of CP. So, matching this constrained is not difficult below the utility pinch, so it is not going to create a constrained in CP matching, because we are using low pressure steam, which has got a very high value of CP. Hence, and why this high value of CP, in fact if steam is assumed to condense or vaporize isothermally, it will have a large value of CP, which is equal to infinite.

So, I had already told that, for a condensing steam or a vaporized steam, the CP value theoretically is infinite. Thus, following the philosophy of starting the design in the most constrained region, the design between the pinches should be started at the most constrained pinch, which is now the process pinch. So, we have identified, that process pinch is the most constrained pinch and not the utility pinch due to this argument. So, now things are very clear, we will start our design from the process pinch and then, we will go away from the pinch in both the directions.

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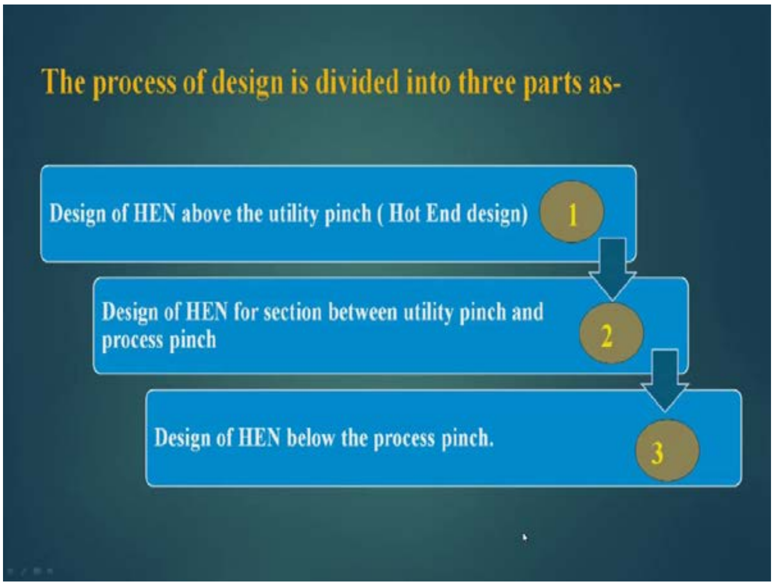


Now, the process of designing is divided into three parts as the design of Hen above the utility pinch we will call it hot end, designing up the section between utility pinch and process pinch and then, design of HEN below the process pinch and we will mark them by 1 2 and 3. So, when I am designing for 1, I am in this region and when I am designing for 2, I am in this region and when I am designing for 3 then, I am below the process pinch.

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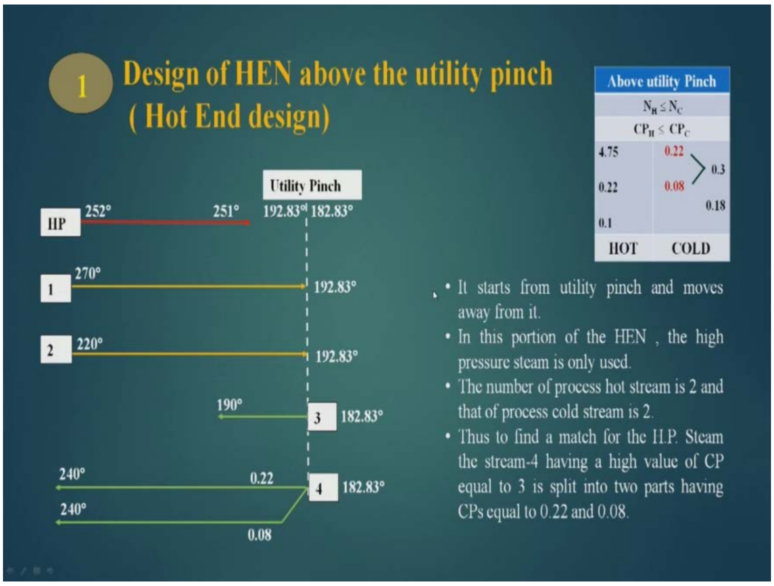


Now, we start the design, design of HEN above the utility pinch, hot end design. Now, it is starts from the utility pinch and moves away from it. In this portion of the HEN, the high pressure steam is only used, we have used the high pressure steam, it will start from here and then, it will go away. In this portion of HEN, the high pressure steam is only used, the number of process hot stream is 2 and that of process cold stream is 2, 2 hot streams and 2 cold streams.

If I consider this utility, it will be now 3, so we said 2 hot process streams, 2 cold process streams and 1 utility. Thus to find a match for the HP stream, stream number 4 having a high value of CP equal to 3 is split into two parts, having CP equals to 0.22 and 0.08. So, what I am doing, if you see, the hot streams are now 3 and the cold stream is 2, so if you see this rule, which tells that N H should be less than or equal to N C. This is not satisfied and hence, I have to break a cold stream into two parts, so I have broken this into two parts. So, this is broken into two parts., so this is my one number design, let see the design of the HEN above the utility pinch, this is a modified diagram, in which this splitting is introduced.

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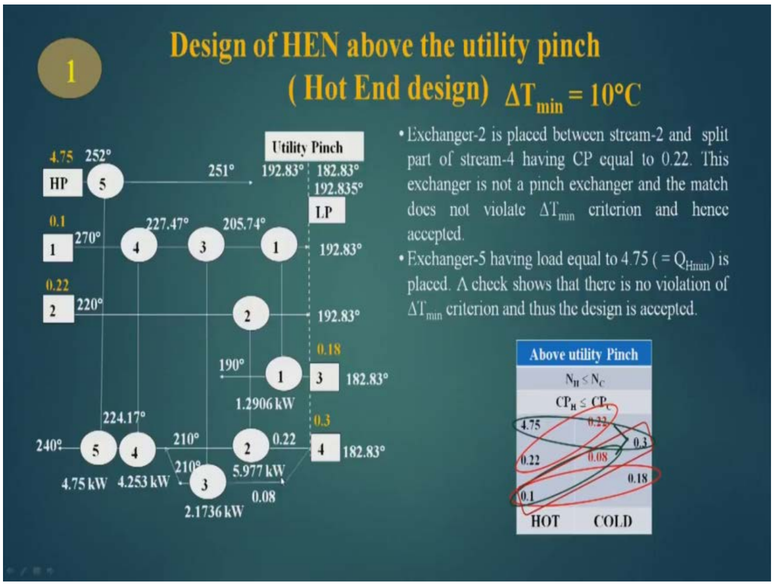


The stream number 4, which has a heat capacity of M C P that is, capital CP is 0.3, it has been spitted into two parts, 0.22 and 0.08. Now, there are 3 cold stream and 3 hot streams, so this is matched. Now, let us put the first match, first match is between 0.1 and 0.18, this is 0.1 and this is 0.18, so you put the match. If we calculate the delta H for stream 3, this is 190 minus 182.83 into 0.18, this is 1.2906 kiloWatt. So, we have transferred 1.2906 kiloWatt to here and this stream which is stream number 3 is now ticked off.

On heat available with stream number 1 is 270 192.83 into 0.1, this is about 7.717 kiloWatt. So, there are some heat available here with this stream, remaining heat, but this is not ticked off. Now, we go for a second match, here also we check that, C P C is greater than C P H, so 0.18 is greater than 1. So, my CP rule is satisfied, I put the second match which is 0.22 to 0.22 and this condition that is, CP condition is now also matched and there is no violation.

So, I put the second heat exchanger here with 5.977 kiloWatt with this stream, this is stream number 2. Now, if I calculate what will be my temperature here, this will be 5.977 divided by 0.22 plus 182.83. So, temperature comes out to be about 209.998 that is, 210 or so, now I can put a third match between 0.1 and 0.08, this is stream number 1 has got a residual heat and a match can put from here to here, because it has got a residual heat.

So, a third match is put between this two, now this temperature 210, this is also 210, if I calculate the heat content of this stream, this comes out to be 210 minus 182.83 into 0.08, this is 2.1736. That means, these two streams, whatever temperature they have, they have given heat to 3 and 2, but 210 to 240, this stream has to be heated up. So, the enthalpy associated with this part and this part is now ticked off, because they have already received the heat from here and here then, we put a match 0.1 to 0.08, we have already taken.

So, put a fourth match here, this is 0.1 to 0.03, so this is 0.1, this is 0.03, so 1 2 4, but it is with the not the splitted part, this is the complete part of this stream and we are transferring 4.5 to 3 kiloWatt. So, remember that, this match is not a pinch match and that is why, the CP rule have been violated to some extent. This is 0.08 is not greater to 0.1, but if we see the temperatures here then, we will find that, delta T minimum is not violated.

Now, the fifth match is from 4.75 here to here, because it has to be, this stream has to be heated up from 224.17 to 240, so we put a fifth match here and this is 4.75 kiloWatt. So, this stream has got a capacity of 4.75 kiloWatt or heat content, it completely transfer to here and then, we reach 240. Now, this match is also violates the CP rule, the black circles violate the CP rules, but as this is not a pinch match, we will find that, it is not violating the delta T minimum criteria.

For example, the input to this stream is 252 and the output is 240, so 252 minus 240 is 12 degree Centigrade and my delta T minimum is 10 degree Centigrade, so there is no violation. Similarly, if I see this, output of this is 227.47 and this is 210, so more than 10 degree Centigrade is available, here also more than 10 degree Centigrade is available. If I see here, this is 210, this is 227, more than 10 degree Centigrade is available and here is this part, this is 205.74 and temperature of this part is 182.83, so more than 10 degree is available.

So, what I see that, though there are two matches which are not adhering to CP rule, but those two matches are not pinch match and hence, some relaxation can be done and relaxation upto the point that, it does not valid the delta T minimum criteria. So, what we see here, in the whole design process, the delta T minimum violation has not been occur.

So, and all this streams have been ticked off, that is why this design can be considered as complete.

Here, we have used the fifth heat exchanger as heater, because this is the utility stream, so you do not see any heater here, but the fifth heat exchanger is a heater. Now, we can calculate, like number 2 stream has a delta H equal 2.3 minus 192.83 into 0.22, so it comes out to be 5.977, so it is passing 5.977 to this, so this is ticked off. Similarly, this is passing heat through 3 heat exchangers and if I add them, this, this and this, so it comes out to be 4.253 plus 2.1736 plus 1.2906, so it comes out to be 771, so this is ticked off. So, similarly this is also ticked off, so if we calculate, we will see that, all the heat contents have been ticked off and hence, it is a complete design of this part.

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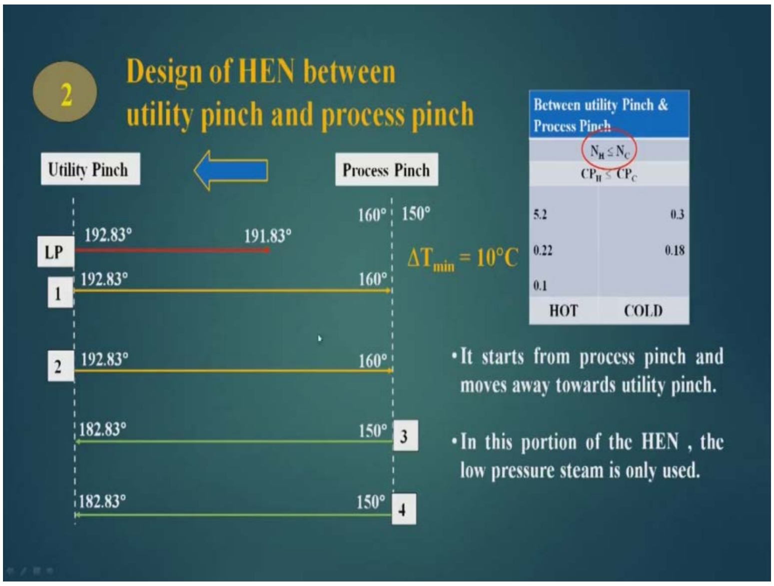


Now, next is the design of the number 2 part that is, between the utility pinch and the process pinch, where there was a confusion in a design direction of the design and then, it was settle, that we will start from the process pinch and go away. Now, we start from the process pinch and go away then, this is the direction of the design. And when we have design the above the utility pinch, the design remains same, so there was no confusion above the utility pinch and below the process pinch.

So, the confusions was between utility pinch and process pinch, so as process pinch is considered to be most constant region of the design, so the design will be in this direction. So, it start from the process pinch and moves away towards the utility pinch and this portion of the HEN, the low pressure steam is only used, this is the low process stream we have used. Now, this is the CP table, now if we see here, this tells that N C should be greater than N H and this violation take place here.

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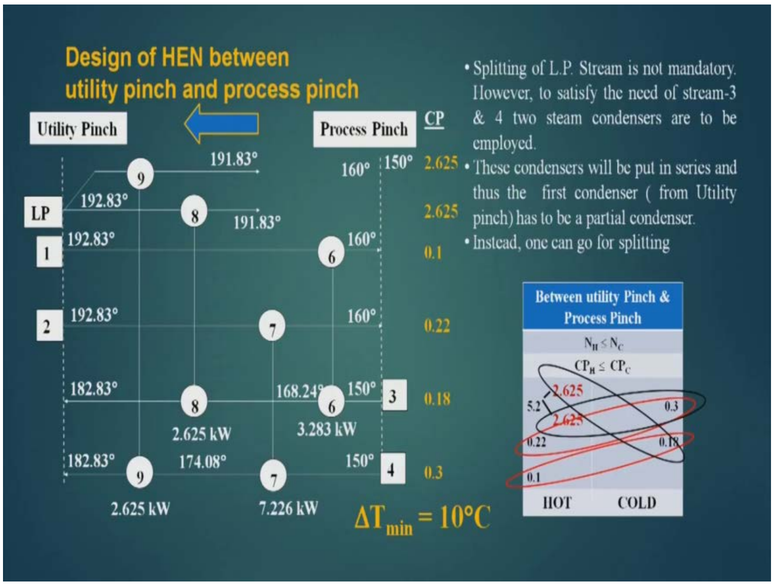


So, to satisfied, now further to satisfy the C P H criteria, the hot stream which is LP stream is now broken into two parts, to satisfied the CP criteria. Now, here it start putting up matches, this 12.18, so C P C is more than C P H. So, the first match is between this, we have gone from 0.1 to 0.18 and the cap is 3.283 and it will heat the stream from 150 degree Centigrade to 168.24 degree Centigrade. Then, we go for 0.22 to 0.3, this is also valid CP match, so we go here 7.226 and this temperature 150, it is heated upto 174.08.

Now, these are two matches, which are pinch matches, so the CP rule has to be followed then, third matches is 2.625 to 0.18, this is violating the CP rule, but this is a non pinch match. As this is non pinch match, we can violate the CP rule to some extent, this is 2.625 kiloWatt. And if we see here, this end is 168 and this end is 191, so delta T minimum is 10 degree, we are achieving this then, we match 2.625 to 0.3, so this is also not vaulting CP rule.

So, this is this match, this is this match and if you see the temperatures, this is 192.83, this is 182.83. So, delta T is there, it is 10 degree, this is 191.83, this is 174.08, so delta T is more than 10 degree. So, what we see that, it is in not violating any delta T minimum criteria and hence, this part of design is complete.

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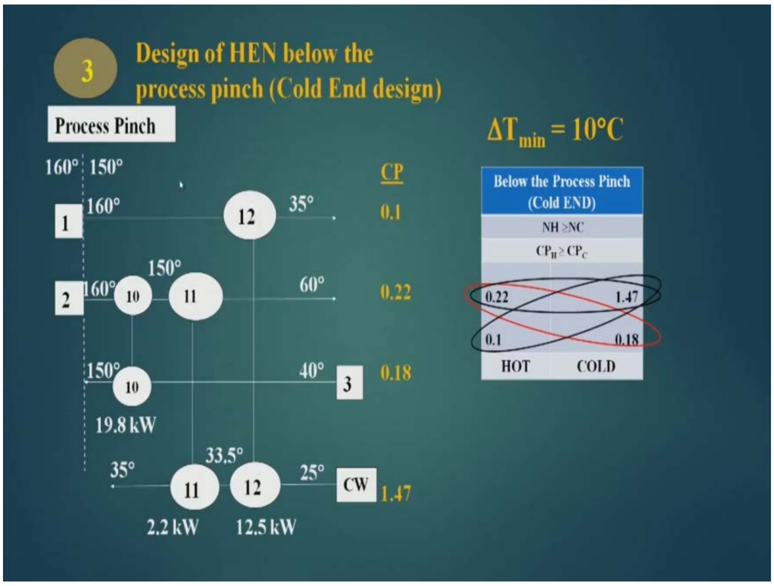


So, we go to the third part of the design, where this is the conditions, so the condition N H is equal to N C, so no problem, we put this match 0.22 to 0.18. So, this is the match, first match, so this 160 drops to 150 due to this match, these are the cold streams, these are hot streams. Second match is 0.22 to 0.147, now if you see this match, this match is violating CP, but this match is not a pinch match and that is why, we can violate this CP to some extent or to the extent that, it does not violate the delta T minimum criteria.

Then, we are matching again 0.1 to 1.47, this is also a violating the CP rules, but this match is also a non pinch match. So, here we see that, this is the 60 degree and this is 33.5 degree, so delta T is more than 10 degree, here this is 60, 35 degree, it is 25 degree, delta T is 10 here and this is 160 degree and this is 33.5 degree, so delta T is a maintain more than 10 degree Centigrade. So now, this completes, because this ticks off all the streams, so this completes our cold end design.

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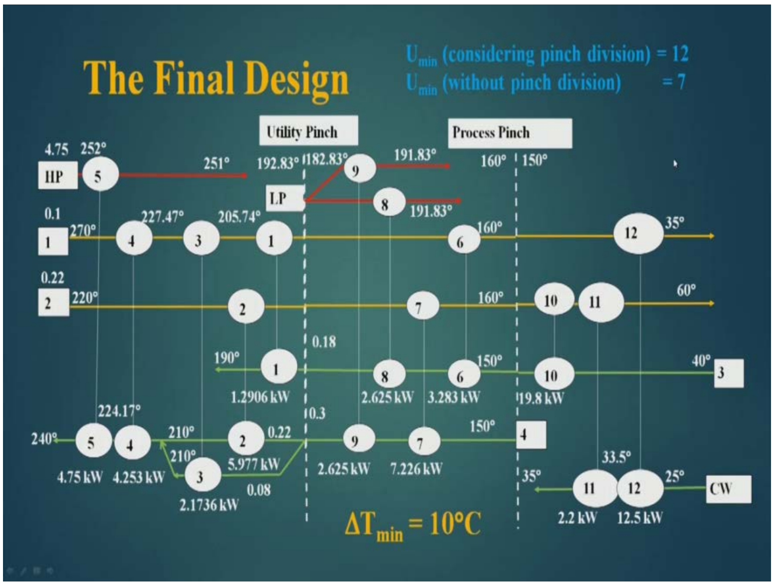


And now, this is the final design of the heat exchanger network, this is above utility pinch, this is between utility pinch and process pinch, and this is below process pinch. Now, one interesting thing we see here, now if we calculate U minimum considering the pinch division that means, low heat is passing through the pinch then, number of heat exchanger is 12 including heaters and coolers, these are two coolers we are using and this is one heater we are using.

So, there are 12 numbers of units and when I am calculating U minimum without pinch division, it is 7. So, there is a possibility of decreasing 5 number of units from this design and whatever design has been produce is a MER design, because we are not allowing any heat to transfer through any pinch, so it is a MER design. And for this MER design, we are providing five more units to meet the minimum hot utility and cold utility criteria.

But, if we consider a non MER design, in which we can pass heat from utility pinch and process pinch, there is chance that, we can decrease 5 number of units, but in that case, the hot utility requirement and cold utility requirement will increase. So, we will be able to decrease the number of unit, but at the same time, the hot utility requirement and cold utility requirement will increase, increasing the operating cost, so there is a trade off. Now, in the next design, we will see this trade off, that if we move from MER design to non MER design, whether it is possible to decrease the total tack by achieving a trade off. Thank you.