Process Integration
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Module - 5
Pinch Design Method for HEN Synthesis
Lecture -1
Rules for Pinch Design Method (PDM) 1st Part

Welcome to the lecture series on process integration. This is module 5, lecture 1, in this module 5 will see the pinch design rules and the design of whole heat exchanger network. So, the topic of this lecture is, pinch design methods, juristic rules part 1 and the pinch design methods in short form is called PDM. First, we will see the pinch design rules and then using these rules, we will design heat exchanger network. Now let us see, what is the heat exchanger network problem?

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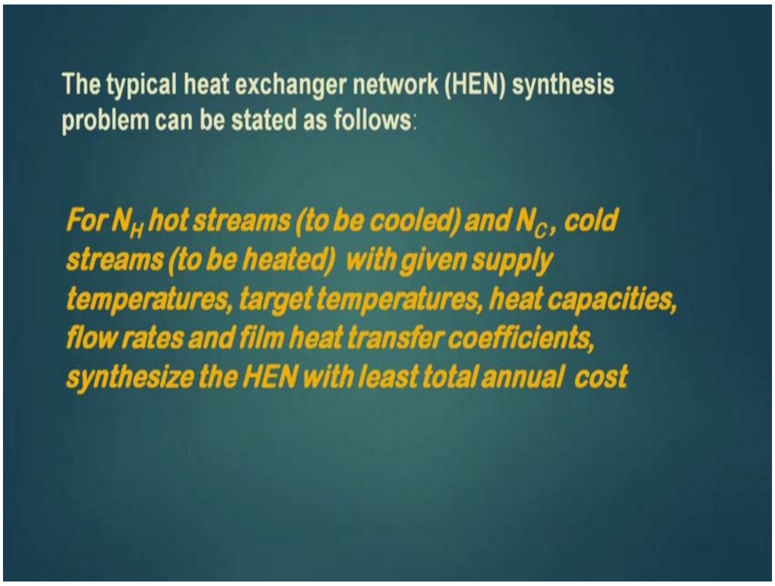

The problem can be stated, as for N H hot streams are that means, if number of streams are N H hot streams are then, it would be cooled. And N C cold in to be heated with given, supply temperatures, target temperatures, heat capacities, flow rates and film heat transfer coefficients, synthesizes the HEN with least annual total cost. That means, the number of hot streams given to us, number of cold streams given to us, the supply temperature is given, the target temperature is given, the heat capacity flow rates are given.

The film heat transfer coefficients are given, hot utility is given, cold utility is given. So, this data is with us then, we have to synthesize a HEN with least total annual cost. This appears to be a simple problem, but this is not that simple, it is a very complicated problem we will see why? As I have told you that, we have to design a HEN, we choose a minimum tax, that is total annual cost. And when we calculate total annual cost, in the cost targeting we have seen that, there are two factors one is called capital cost factor and other is called operating cost factor.

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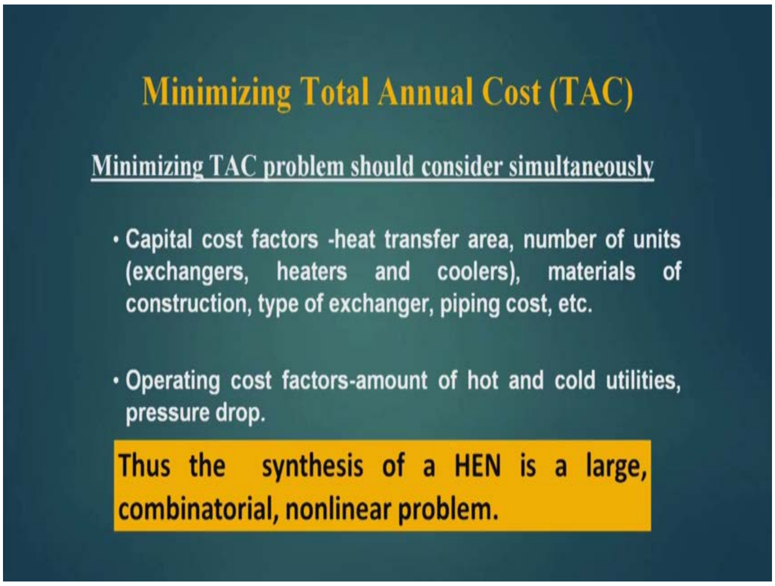

The capital cost factor is dependent on heat transfer, area number of units that is exchangers, heaters and coolers, the material of construction of this exchangers, heaters and coolers. Type of heat exchangers we are using there, piping cost etc. etc. and the operating cost includes, the amount of hot and cold utilities we are using and that cost. The pressure drop for pumping the liquid to the heat exchangers and for that pressure drop, is spent electrical energy so, fast of that electrical energy.

Now when we designing a HEN, within the framework of rules and regulations of pinch then, the large amount of heat exchangers, large number of heat exchanger network can be designed. And their capital cost will differ, their operating costs will differ and hence, the total annual cost should differ. So, that is the synthesis of HEN is a large combinatorial and non-linear problem. Now let us see that, when we are synthesizing a HEN, what are the different spreads offs.

Now, we can have different stream speeds in a heat exchanger network, that will have different costs, number of the exchanger will change, number of sales in a heat exchanger can change. Number of units in a heat exchanger can change, this can give, but to different topologies and the area of those topologies can change. Based on delta t minimum, the operating costs can change.

So, that is the tradeoff between different variables and the heat exchanger network which we will design, will the tag of that exchanger will change a lot. And we have seen that, there is different design will involve with delta t minimum also. And then, we have to find out the delta t minimum, optimum also. Once a large number of heat exchanger networks are design then finally, we have to select one heat exchanger network, which will give us the minimum cost. And will also offer at same time, the rumors of the operation.

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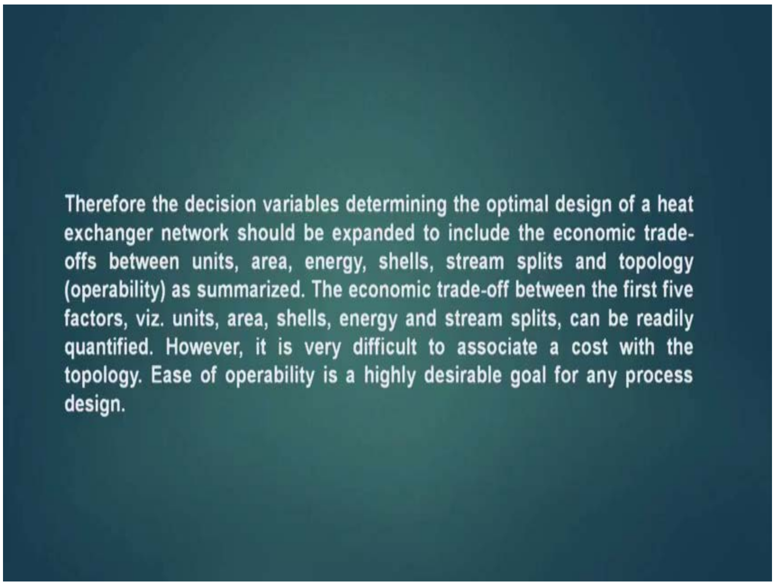

So, if we conclude it with a decision variables, determining the optimal design of a heat exchanger network should be expanded to include, the economic tradeoffs between units, area, energy, shells, stream splits and topology operability as told earlier. The economic trade of between the first five factors that is units, area, shells, energy and streams splits can be readily quantified. However, it is very difficult to associate a cost with the topology, ease of operability is a highly desirable goal for any process design. So, there are few parameters which can be quantified, there are other few parameters which cannot be quantified so easily. So, within this framework, within this background, we have to create the design which will be satisfying our constants.

Now, the pinch designs start with a processes flow diagram, before we apply the pinch technology or the process integration principles, which can be carried out is in pinch technology or pinch analysis. Starts with a process flows it with decide to which process, part of the process flows it or process flows it, we will going to apply our process integration principles. Then from this process flows it, a typical stream table is extracted so, this stream table looks like this, it is a typical stream table of hot and cold streams.

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Stream Number	Stream Type	Heat Capacity Flow Rate (kW / ^{0}C)	Source Temperature (^{0}C)	Target Temperature (^{0}C)
1	HOT	3	200	65
2	HOT	6	90	30
3	COLD	3.5	30	142
4	COLD	4	25	130

A typical Stream Table showing Hot & Cold stream data

And then from this stream table, which can have other important columns also, as heat transfer coefficient, cost of utilities, cost of heat exchangers, formula etcetera.

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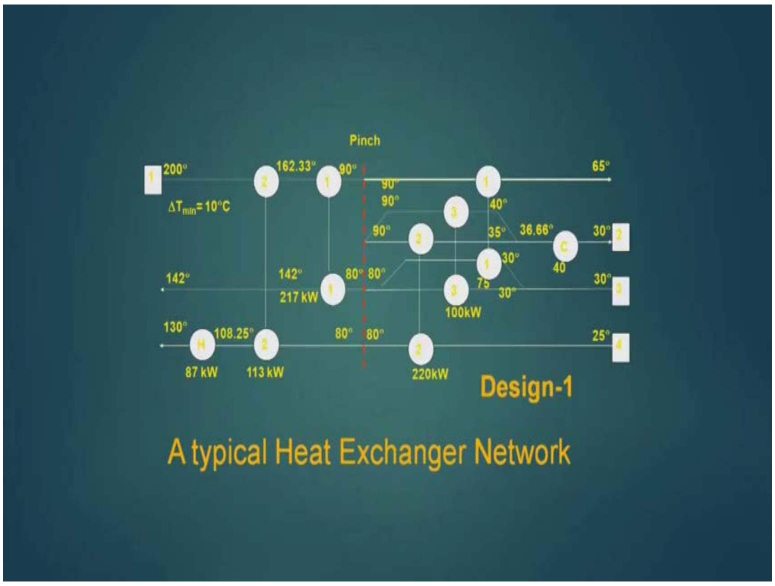

Then, the final is a typical heat exchanger networks, which looks something like this. So, we start with a flows it, will design heat exchanger network. Then, we simulate its operability, its stability we see and then, we modify the process flows it, according to the design. So, that is our result, we choose onto achieve by using the process integration principle and what we gain, that a operating flows it which will operate with, far less cost than what it was before.

What are the benefits of using pinch design method? As we have already told that, the process integration pinch design method is not the only method, that can be other means to carry out the process integration. But in this lecture series, we will be using pinch design methods and we should know that, what is the benefit of pinch design method?

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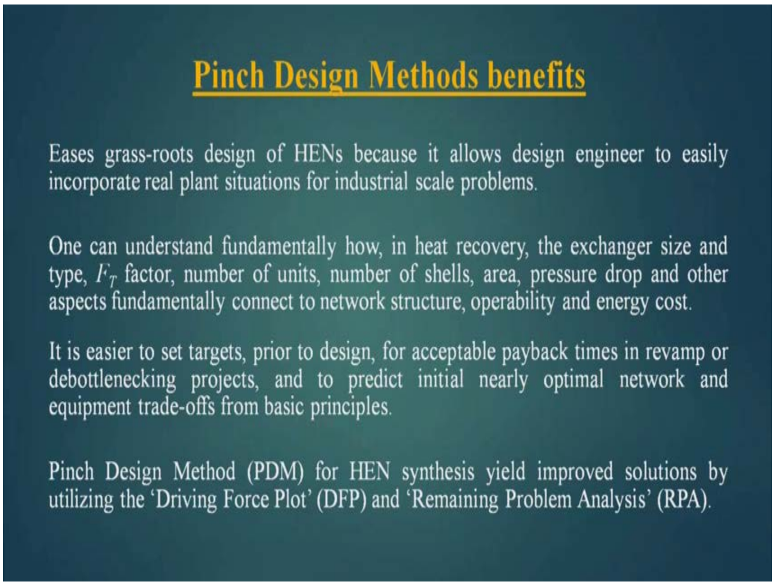

It is in grass root design of HENs, allows design engineered to easily incorporate real plant situations for industrial scale problems. That means, involvement of operators and designing engineers and framing the design of heat exchanging networks. One can understand fundamentally how, in heat recovery the exchanger size and type F T factor, number of unit number, shells, area, pressure drop and other aspects fundamentally connect to network structure, operability and energy cost. So, it gives us the fundamental information's required or the insight required, to design a heat exchanger network and how the other parameters of the design, of it, the design.

It is easier to set targets prior to design, these are very important factors of pinch design, it sets targets react prior to design. And during the design, we come close to the target so, it is easier to set targets prior to design for acceptable payback times, in revamp or bottlenecking project. And to predict, initial nearly optimal network and equipment tradeoffs from the basic principles. So, designs are very close to the optimal network, design pinch design methods. Which is in the short firm called PDM for HEN, synthesizes heat exchanger networks, yields improved solutions by utilizing the driving force plot and remaining. problem analysis.

There are two such techniques in the PDM, which is called driving force plot and remaining problem analysis. By using the driving force plot, we can know that why a heat exchanger network which is called, network 1 has got more area than network 2 though, both are satisfy our need. If I am purely using my driving force in the network, my area will increase and if I properly distributing the driving force, throughout the heat exchanger network, then its area will be less. So, this magic which pinch design offers that it distributes the driving force properly, throughout the area or the throughout the network.

And hence, more you do it more we go close to the optimal network, the remaining problem analysis basically gives us direction, while designing the heat exchanger network using pinch technology. Whether, I am moving in the right path or not is given by remaining problem analysis.

So, it is just like a guide which guides us through the right path so that, while designing we do not deviate and move into the wrong path. Wrong path means we will not achieve the targeted area or the targeted cost so, if you use remaining problem analysis it will drive us in the right path so that, we meet the targets which we have set for the designing of prior to this design.

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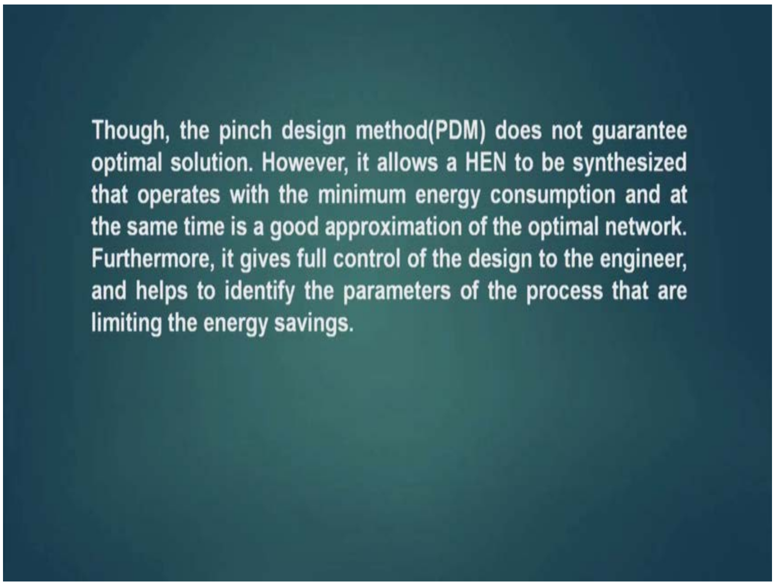

Though the pinch design method does not guarantee optimal solutions, however it allows a HEN to be synthesized, that operate with the minimum energy consumption. And at the same time is a good approximation of the optimal network, furthermore it gives full control of the design, to the engineer and helps to identify the parameters of the process, that are limiting the energy savings. So, it has got a practical outlook and it gives you a lot of insight while, pinch design method is used for the design of heat exchanger network. So, there are three important steps in the HEN design the first important step is targeting.

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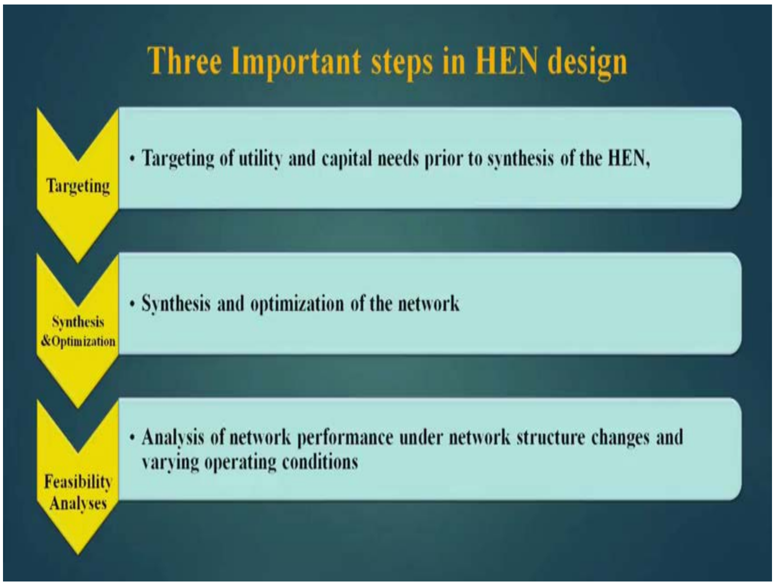

We have learned the targeting of utility and capital needs prior to synthesis of the HEN, this is a very important factor in the HEN design, using pinch technology. Then comes, synthesis and optimization after the targeting stage, the synthesis of heat exchanger network is done and a large number of networks are designed and the optimum network is selected out of it. We are seeing that the HEN design is also a function of delta t minimum and a delta t minimum optimum is obtained, for which the heat exchanger network cost is minimum.

Once the design is available with us or we called it optimum design is available with us, the analysis of the network performance under network structure change. And varying operating conditions are done, you will remember that in the stream table, the supply and target temperature of different streams are constant, they are not changing. However, in a industrial environment this temperature change considerably.

Now, if we are designing a heat exchanger network for fixed supply and target temperatures, it may not work properly when these temperature are changing in a industry. So, the selected HEN has to be tested for varying operating conditions and we have to see that, the structure of the HEN is stable. And it is not creating problems, in terms of meeting the target temperatures of different streams and for that, the feasibility analysis is conducted after the design.

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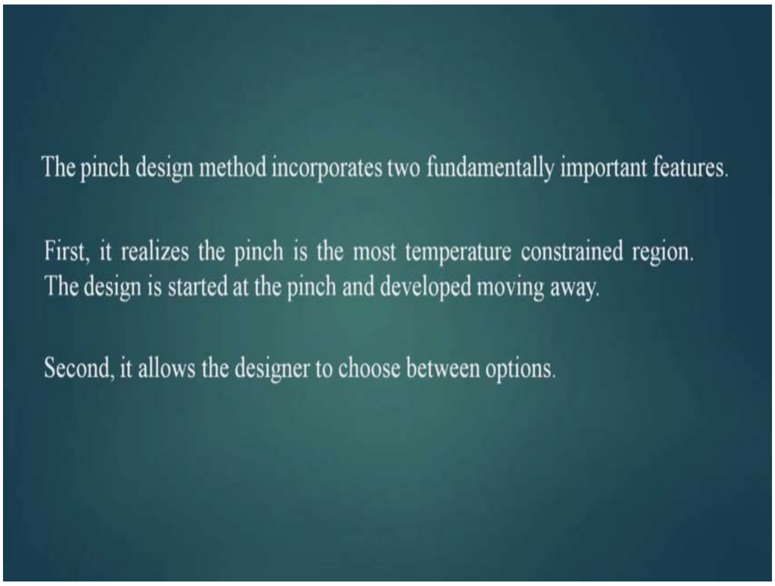

Pinch design method incorporates two fundamentally important features. The first feature is, it realizes the pinch, is the most temperature constrained region. If is see the GCC or composite curve then, we will immediately find that is the pinch is most temperature constrained region. So, delta t is minimum at pinch and this is called delta t minimum. So, the heat exchangers which will come around pinch will have large area. So, pinch it the most temperature constrained region and I cannot violate delta t minimum criteria because, if it is violated the hot utility requirement and cold utility requirements change.

The once it is realized that pinch is the most temperature constrained reason, the pinch design method tells that the design should start at the pinch. And it should be developed moving away, that means we should start our design from the pinch and then, we can move away from the pinch. We will explain it more, second it allows the designer to choose between options, while designing a large number of options will come and a designer can select options. Now, it clearly depicts that how the design should start.

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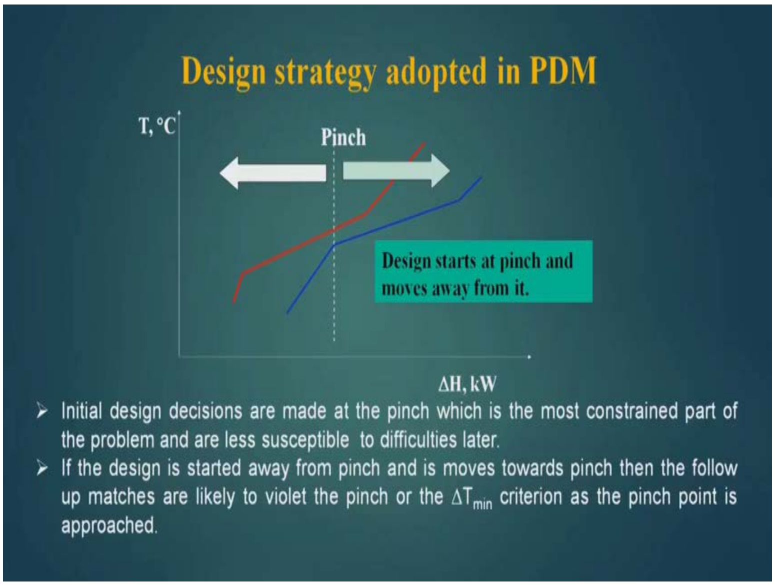

The design should start from here at pinch and this, then should go away from the pinch, for this side also and for this side also. So, this is above pinch area and this is the below pinch area. So, for above pinch area we know that, the pinch, divide the problem into two parts, above pinch area and below pinch area.

So, for above pinch area the problem will start from pinch and then it will move away in this direction because, at the pinch is delta t minimum, but when we move away from the pinch, the delta t opens up. That means, delta t is more than the delta t minimum similarly, for below pinch design we will start from pinch and then, will move away. Here also when we are away, the delta t available for design is more than the delta t minimum.

Initial design decisions are made at the pinch, which is most constrained part of the problem and are less susceptible to difficulties later. So, if I start from here and go away the difficulties will be more, will be less and if I come from here to here then, difficulties will be more in matching this condition. If the design is started away from the pinch and is moves words the pinch then, the follow up matches are likely to violate the pinch or the delta t minimum criterion, as the pinch point is approached.

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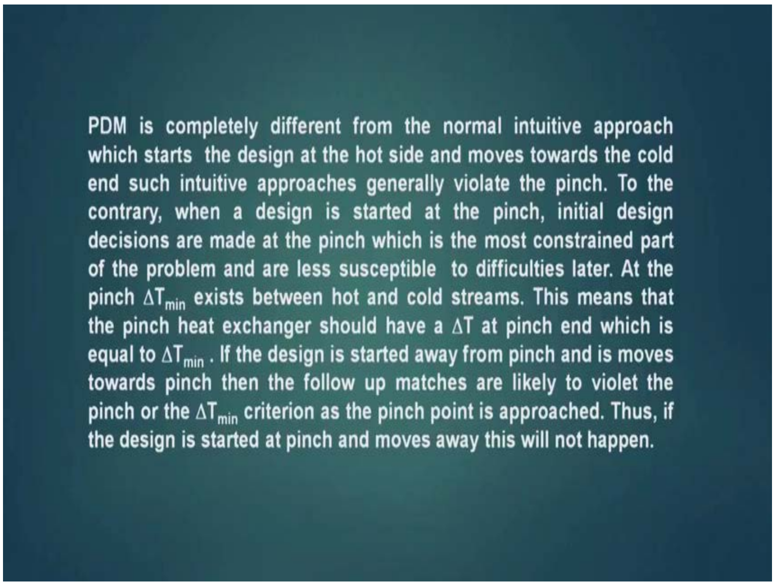

The pinch design method which is called PDM is completely different from the normal intuitive approach, which starts the design at the hot sides and moves towards the cold end. Such intuitive approaches generally violate the pinch and we know if we violate the pinch, the taxation is double. To the contrary, when the design is started at the pinch initial design decisions are made at the pinch, which is the most constrained part of the problem and are less susceptible to difficulties later.

At the pinch delta t minimum exists between hot and cold streams, this means that pinch heat exchanger should have a delta t, at pinch end, which is equal to delta t minimum. If the decision is started away, if the design is started away from the pinch and is moves towards the pinch then, the follow up matches are likely to violate the pinch or the delta t minimum criteria, as the pinch point is approached. This is the reason, why we start the design from pinch and go away from the pinch and not in the reverse direction.

Thus, if the design is started at pinch and moves away, this will not happen, that means violation of delta t minimum at the pinch will not happen, if we start the design from the pinch and go away in both sides. Now, if we see the feasibility criteria at the pinch, there are many feasibility criteria for the design of heat exchanger network.

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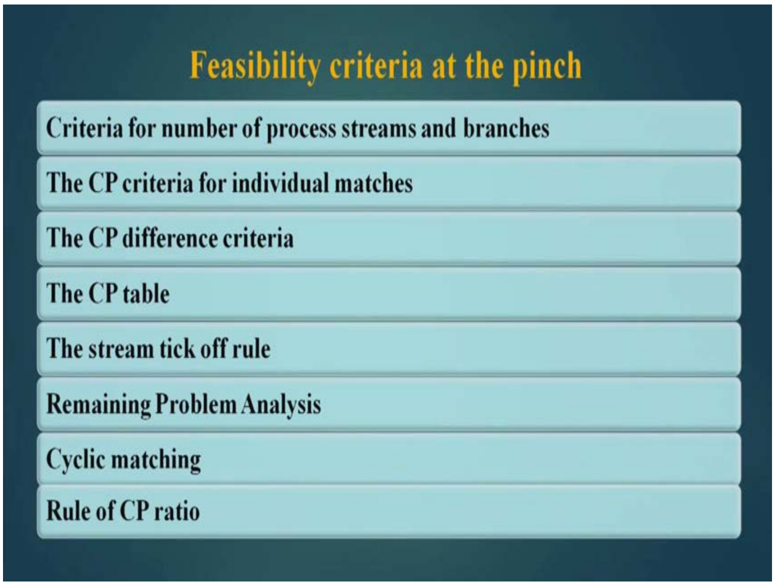

The criteria for number of process stream and branches, the CP criteria for individual matches, the CP difference criteria, the CP table, the stream tick off rules, remaining problem analysis, cyclic matching and rule of CP ratio. In these lectures, will see a few of these criteria and then in other lectures will see the remaining criteria. Now, let us define what are the pinch exchanger because, this word will be use extensively and pinch rules are very strictly followed for pinch exchangers. And that is why it is necessary that we should know what are pinch exchangers?

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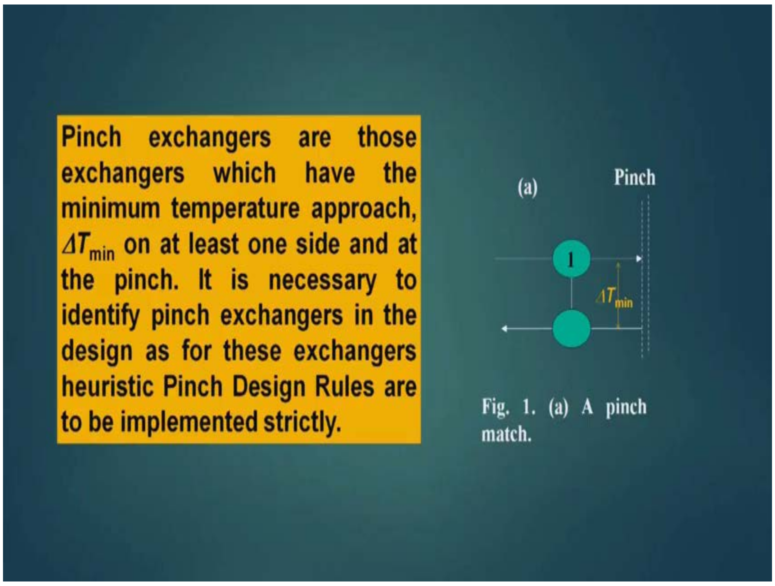

Pinch exchangers are those exchangers, which have the minimum temperature approach delta t minimum on at least one side and at the pinch. It is necessary to identify pinch exchangers, in the design. As for these exchangers heuristic pinch design rules are to be implemented strictly. Now, if you see this figure this is heat exchanger 1, if you see this pinch side of it, these are the two streams, which are touching pinch.

And the difference between this end of the heat exchanger is delta t minimum. So, at least one end of the heat exchanger and delta t minimum then these and may not have delta t minimum or it may be more than delta t minimum and it will not be less than delta t minimum. So, this heat exchanger is a pinch heat exchanger or we called it as pinch match.

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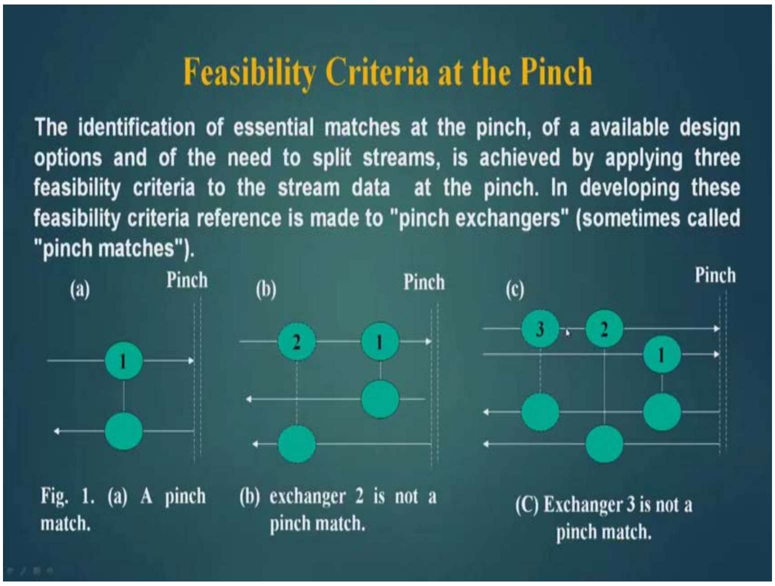

The identification of essential matches at the pinch of a available design options and of the need to split stream is achieved by applying, three feasibility criteria to the stream data, at the pinch. At the pinch is very important for us and there are a lot of restrictions at pinch so, we will use three feasibility criteria for the pinch matches. Now, here let us see again what are the pinch matches this is obviously a pinch match, this is a pinch match, but this is not a pinch match.

So, exchanger 2 is not a pinch match, here exchanger 1 is a pinch match exchanger, 2 is a pinch match, because it different between this and this temperature delta t minimum, but exchanger 3 is not a pinch match. We will see that in the pinch, it may be useful to split a stream there will find out rules behind this. So, let us try to understand the difference between streams and the branches.

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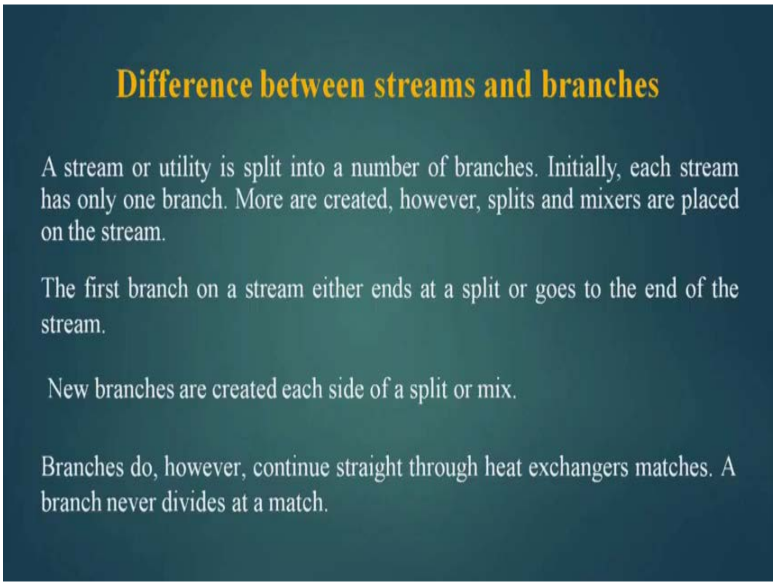

A stream or utility is split into a number of branches, initially each stream has only one branch, more are created. However, splits and mixers are placed on the streams, the first branch on a stream either ends at a split or goes to the end of the stream, this will see when, is split a stream. New branches are created each side of a split or mix, branches do however continue straight through, heat exchangers matches, a branch never divides at a match.

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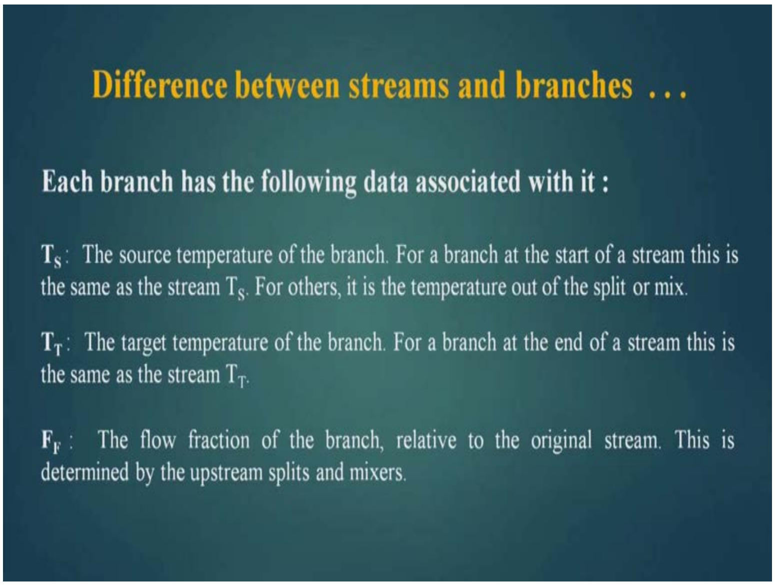

What are the difference between streams and branches, each branch has the following dada associated with it. T s that is, supply temperature or the source temperature, the source temperature of the branch, for a branch at the start of a stream, this is the same as the stream T s. For others it is the temperature, out of the split or mix similarly, T t which is the target temperature of the branch, for a branch at the end of a stream, this is the same as the stream T t.

And F f the flow fraction of the branch related to the original stream, we can say that the branch stream is 10 percent of the original stream or 20 percent of the original stream. So, we divide the streams and then we write down what is the value of F f, this is determined by the up streams and mixers. Now, let us see the first feasibility criteria, the number of process stream and branches. Now, let us developed this criteria.

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The first feasibility criteria concerns the stream population at the pinch, it is what should be the stream population, when I say stream population, the stream population of hot streams as well as cold streams. The population of hot and cold streams has to be such that, it will allow an arrangement of exchangers compatible with minimum utility usage. This will be more clear that at the pinch, the number of hot streams and number of cold streams should be such that, an arrangement for the exchange can take place so that, the utility usage is minimum. Now, let us this, take this problem where there are three hot streams and two cold streams at the pinch. So, hot streams are not equal to cold streams here.

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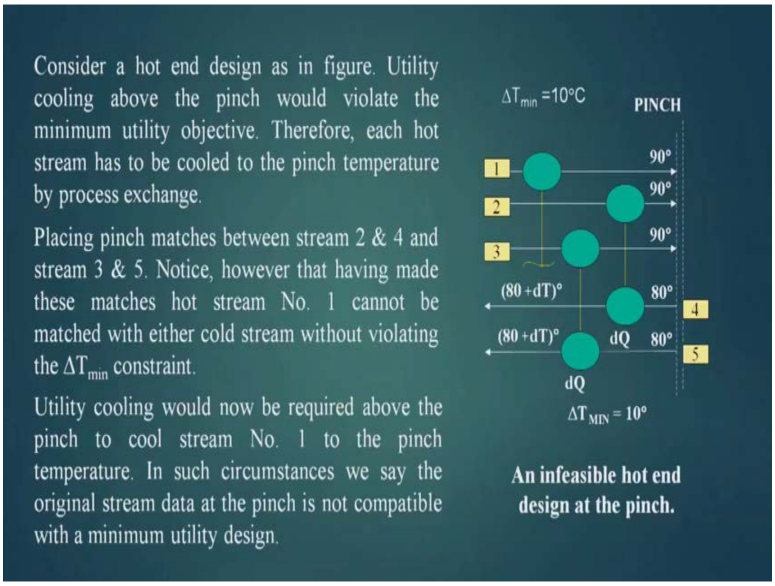

Now, suppose we put to matches here between hot stream 2 and cold streams number 4, hot steam 3 and cold stream number 5. If suppose d Q amount of heat is pass from 2 to 4, this temperature 80 degree will increase now. Similarly, this 80 degree temperature will increase by passing of d Q amount of it. Now, if it is so, then there will be a problem in matching, which is low that the pinch divides the problem at two parts, upper pinch and lower pinch or hot end and cold end.

This picture shows hot end design, in the hot end we cannot use the cold utility similarly, in the cold end we cannot use the hot utility. Now, if placing pinch matches between 2, 4 and streams 3, 5 notice, however that have been made this matches hot steam 1 cannot be matched with either cold streams, without violating delta t minimum constraint.

Now, we have put match between the stream 2 and 4 and 3 and 5. Now, this stream has a temperature delta t plus 80 plus delta t, 80 plus delta t now if I am matching this, then this temperature 90 and delta t plus will violate the delta t minimum criteria. And once the delta t minimum criteria is violated, I cannot the put the match.

And if I cannot the match then, how this stream 1 will reach to 90 degrees centigrade unless; otherwise it gives it heat to the cold stream. Now to solve it, I have to cool this stream number 1 with cold utility and we all know that, at the hot end I cannot use cold utility, because if I used it the penalty twice and that will increase the utility demand of the HEN.

So, it is not advisable now then what is the solution? Utility cooling would now be required, above the pinch to the cool steam number 1 to the pinch temperature. In such circumstances, we said our original stream data at the pinch is not compatible with the minimum utility design. So we cannot go for minimum utility design so, what is the way out?

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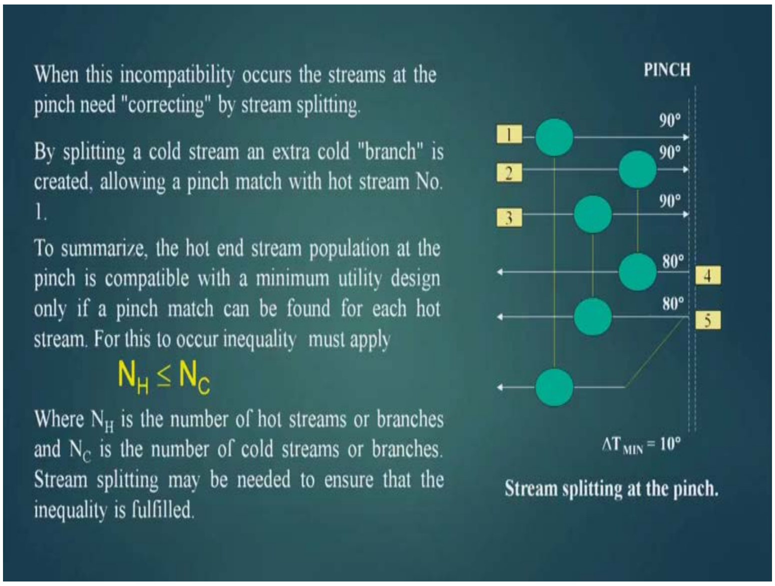

Now by splitting a cold stream an extra cold branch is created, allowing a pinch match to the hot steam. So, the solution is splitting a steam at the pinch so, if I split this original team into two parts, one part this, another part this then, the temperature of this part will increase 80 plus delta t. But the temperature this part remains at 80 degree centigrade and hence, I can put a match from 1 to the split stream of number 5.

So, this solves the problem that means, there will be situations when we have to split the streams. Now, let us analyse why this happened, to summarise this the hot end stream population at the pinch is compatible with a minimum utility design. Only, if a pinch match can be found, for each hot steam. If I am not able to provide, pinch matches for all the hot streams then, there will be a problem and to and for this to occur inequality must apply. And what is that inequality, number of cold steam should be greater than number of hot steams or equal to hot streams. In this case, there are three hot streams and there are two cold streams.

So, number of cold streams were less than the number of hot streams and that is why we have to face this problem. And when we splitted the number of, steam number of 5 into 2 streams, now the number of cold stream become 3, number of hot streams are 3. So, N H is equal to N C and hence the problem solved so, for hot end design, the number of cold streams should be greater or equal to the number of hot streams.

If a matching without any cold utility has to be carried out so, this is a rule which we form and this is a pinch design rules about the stream population. So, where N H is number of hot streams and branches and N C is the number of cold streams and branches. Stream splitting may be needed to ensure that, the inequality is fulfilled.

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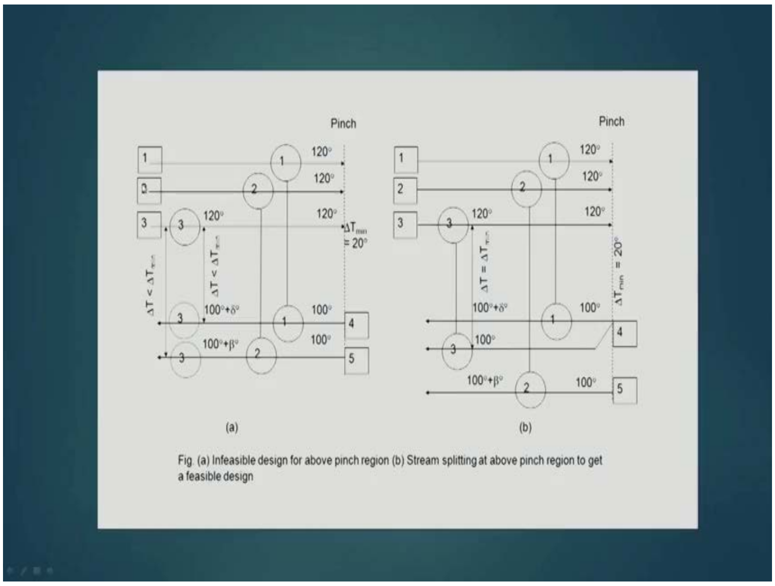

Fig. (a) Infeasible design for above pinch region (b) Stream splitting at above pinch region to get a feasible design

Now, these are another examples here also there are 3 hot streams and 2 cold streams, the temperatures are different when we pass the heat from 1 to 4 and 2 to 5 then, the temperature increases. So, I cannot put the match between 3 and 4 or 3 and 5 and two solve this, I have to split stream number 4 so that, delta t minimum criteria is not violated.

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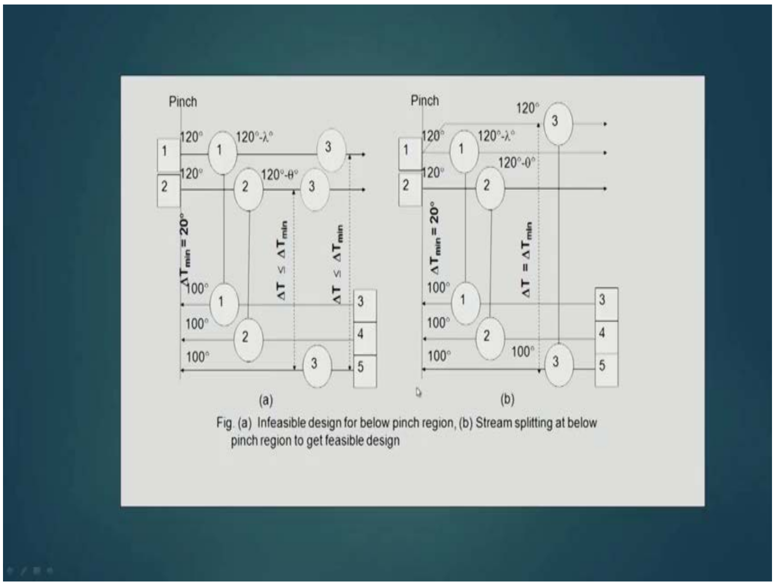

Similarly, for the cold end design we see this problem, there are 3 cold streams available and are 2 hot streams are available. So, now when the heat is pass from stream number 1 to stream number 3, stream number 1 to stream number 3 and stream number 2 to stream number 4, this temperature stopped. This is 120 minus data and 120 minus delta now, if I put another match from this to this, this violate delta t minimum criteria. And hence, for this case also stream splitting is done and then I put a match between this splitted stream and the stream number 5 and this now do not violate the delta t minimum criteria.

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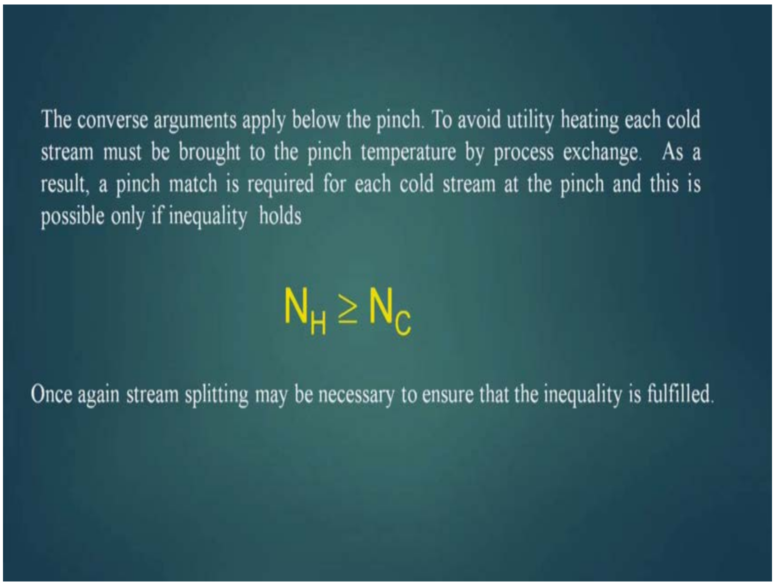

So, we have seen the rule required for the hot end design similarly, we have seen a rule which is required for cold end design. So, the converse argument apply below the pinch, to avoid utility heating each cold stream must be brought to the pinch temperature, by process exchange.

As a result, a pinch match is required for each cold stream at the pinch and this is the possible only if, this is inequality holds that is N H is greater or equal to N C. Once again, stream splitting may be necessary to ensure that the inequality is fulfilled and if I do not fulfilled this, then there is a chance at cold end, I have to use hot utility for heating a cold stream, to come to its temperature.

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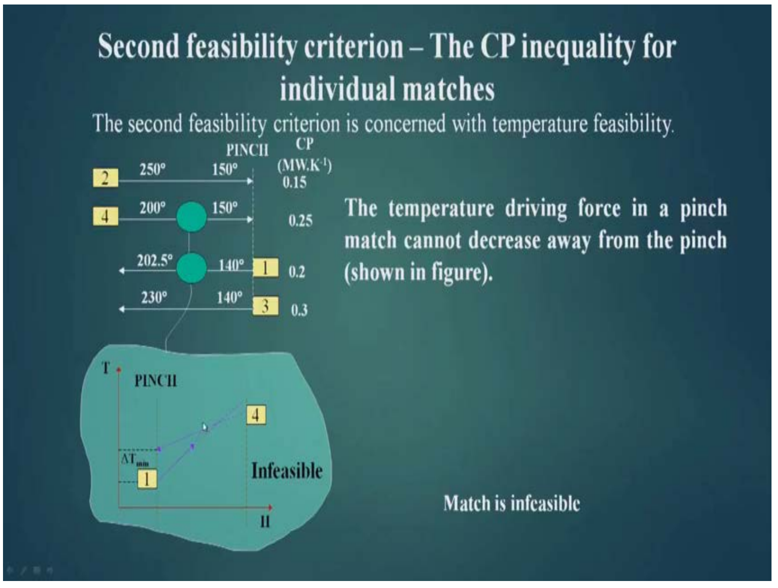

Now, the second feasibility criteria, the CP inequality for individual matches, now the second criteria is what, it tells about the matches that means, the stream should be matches with streams, which hot streams should be match with cold streams. The second feasibility criteria is concerned with temperature feasibility, this is the small problem is seen, there are 2 hot streams, 2 cold streams.

Now, let us suppose match between hot stream number 4 to cold stream number 1. Once we put this match, the temperature of the changes to 202.5 so, the delta t minimum criteria between this is violated. May, if I saw the temperature profiles, this is my pinch line, here I have delta t minimum that means, delta t minimum is here 10 degree centigrade. And when I go away from this pinch, towards this direction I see there is temperature cross.

That means the delta t minimum is decreasing when I am going away from pinch and if it will happen and there is a 100 percent chance of delta t minimum violation, which I do not want. So, let us analyze under which condition this happens so, this is a infeasible match because, this match violates delta t minimum criteria is in the other end of the heat exchanger.

The temperature driving force in a pinch match, cannot decrease away from the pinch as shown in the figure. So, what is required it should diversified that means, this delta t minimum is here so, away from this pinch. So, this delta t increase than the delta t minimum and it do not converse so, we have to find out a situation why this diversions will take place.

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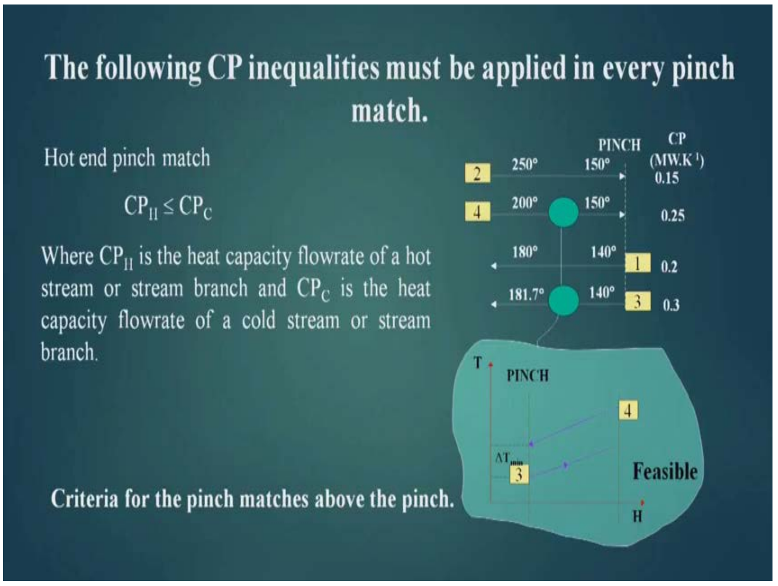

Now, here we see that when we will put match between 4 and 3, this diversions take place and now, the delta t available here, is very less that means, larger than 10 degree centigrade, which is available here at the pinch. So, this is diverging that means, delta t is available here, here or here is more than this. So, this is a proper matching, this matching is a proper matching, but what made this, if we analyse this has something to do with this CP value.

So, for hot end design this CP C should be greater or equal to CP H, if you maintain this then our profiles will diverge from the pinch. And if it is reverse it will converse so, where CP H is the heat capacity flow rate of a hot stream or stream branch and CP C is the heat capacity flow rate of a cold stream or stream branch.

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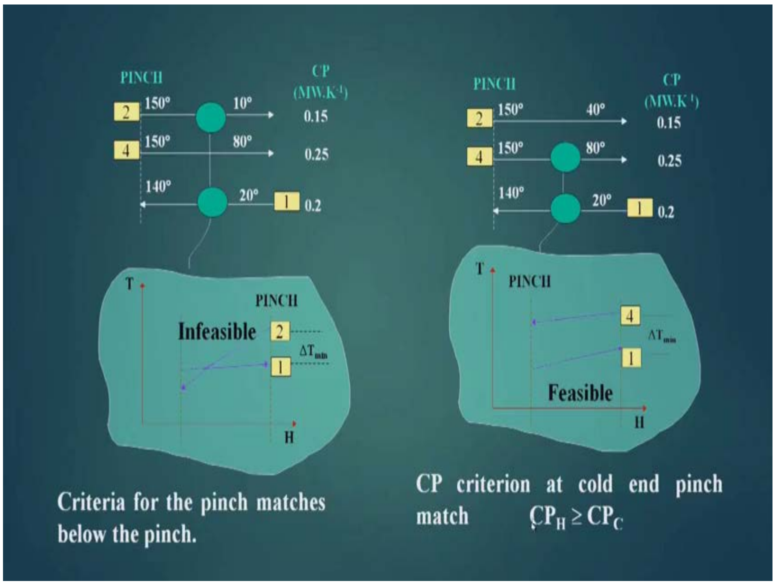

Now, let us analyze for cold end. So, this is a cold end design, a matching 2 with 1, this is the pinch delta t, again it converse and there is a cross. In this design, there are matching 4 with 1, this is the pinch so, it is diverging, this starts from the pinch and this is the diverging. And hence, it is acceptable this pinch will be here so, it starts with the pinch delta t minimum and then, it is diverging. So, this is acceptable so, this is the feasible design. So, to get such type of diverging that means, delta t diverges out from the pinch, the criteria for the cold end pinch CP H, should be greater or equal to CP C.

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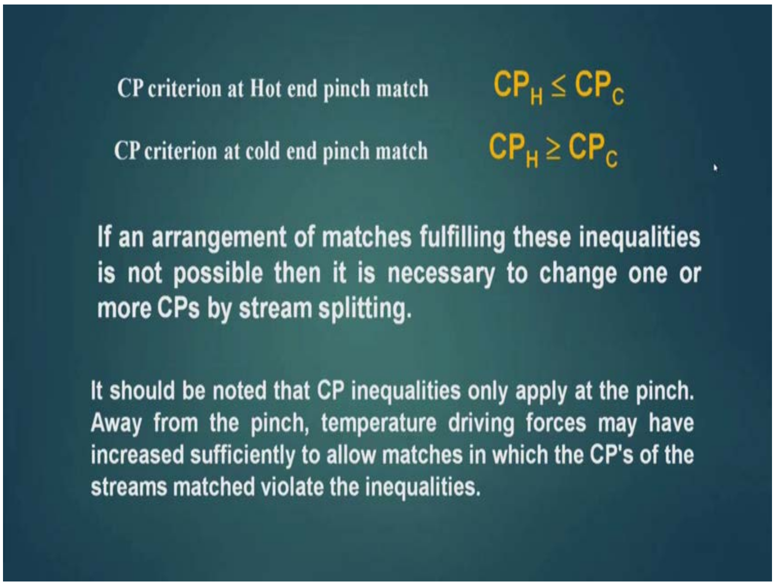

So, for individual stream matching the, CP criteria at hot end is CP H should be less than or equal to CP C. This CP criteria, at cold end pinch match, CP H should be greater or equal to CP C. So, while doing match if I had to this criteria then, the temperature profiles will open up or diverse and chances of delta t minimum violation, will not take place. If an arrangement of matches fulfilling this inequality is not possible then, it is necessary to change in one or more CP's by stream splitting.

So, the CP criteria should be supported by stream splitting criteria we will see that, how to combine these to criteria in the next lecture. It should be noted that CP inequalities only apply, had the pinch this is very important. I have told you that, the criteria which we are forming in these lectures are to be sacrosently applied to the pinch heat exchanger. Why? Because, for pinch heat exchanger one end of the heat exchanger delta t minimum, but if I go away from the pinch, the delta t available are more than the delta t minimum.

So, to some extent we can slag this criteria so, away from the pinch, temperature driving process may have increase sufficiently to allow matches in which CP's stream matched, violate the inequalities. So, we will see that even if these inequalities are violated away from the pinch, delta t minimum violation does not take place. And hence, we can tolerate the violation of this criteria, away from the pinch to the extent that, they do not violate delta t minimum criteria. Now, third criteria is feasibility criteria and that is called CP difference criteria.

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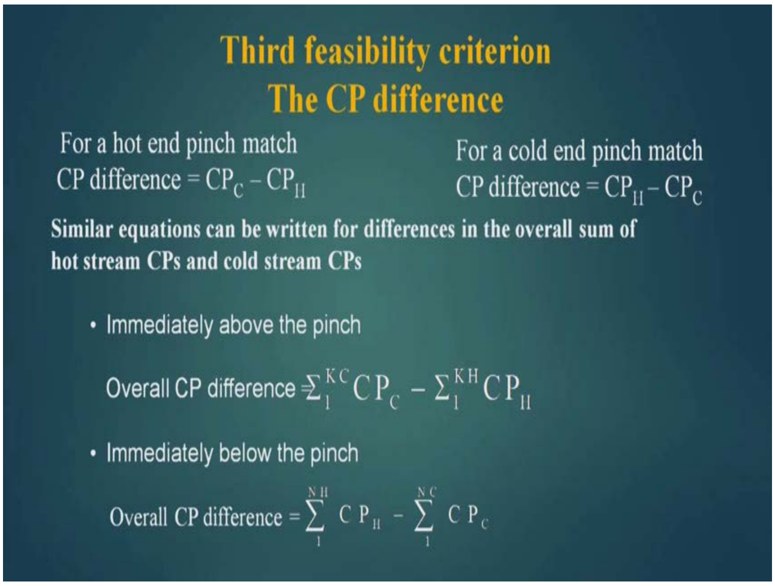

So, for hot end pinch match CP difference is CP C minus CP H for a heat exchanger. Similarly, for cold end pinch match for heat exchanger CP difference is CP H minus CP C. Similarly, the equations can be written for differences in the overall sum of hot stream CP's and cold stream CP's and it can apply to the above pinch and below pinch.

So, immediately above the pinch overall CP difference is summation of CP C minus summation of CP H, values of the pinch and immediately below the pinch, overall CP difference is summation of CP's of hot stream minus summation of CP's of cold streams. So, here will see that is got something to do, with the value calculated based on this and the value calculated based on this.

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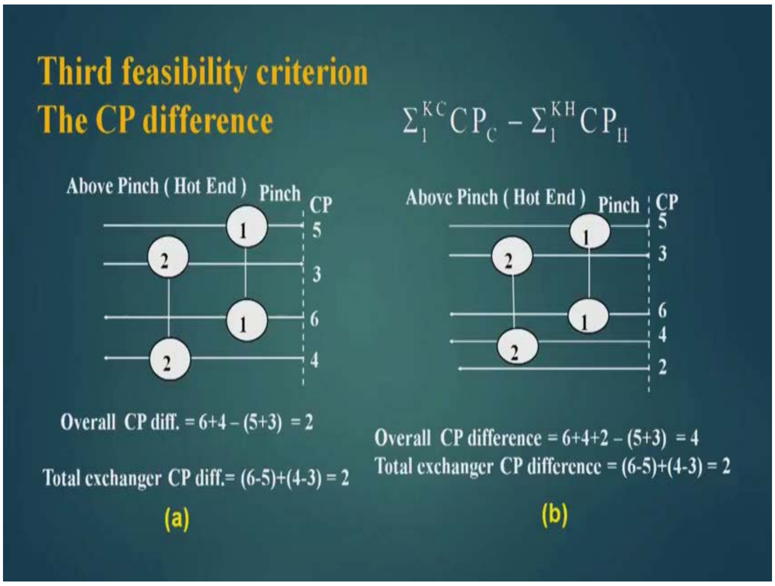

So, we take the hot pinch area now, the overall CP difference in 6 plus 4, this is the CP of two cold streams, 6 plus 4 minus two hot streams, 5 and 3, 5 plus 3. So, this overall CP difference is 2 so, I am using this equation and individual CP differences that is total exchanger CP difference if you see then this exchanger matching with this so, this is 5 minus 5 and for this is exchanger this is 4 minus 3.

So, it comes to be 2 so, here overall CP different is equal to total exchanger CP and both are to 2. Now, let us take a, b now here there are three cold streams and there are two hot streams so, if I use this formula because it is hot end, this formula will be used. So, this is 6 for plus 4 plus 2 minus 5 plus 3 comes out to the 4 and total exchanger CP different this is 6 minus 5, 6 minus 5 for heat exchanger number 1 and for heat exchanger number 2, this is 4 minus 3 is 2.

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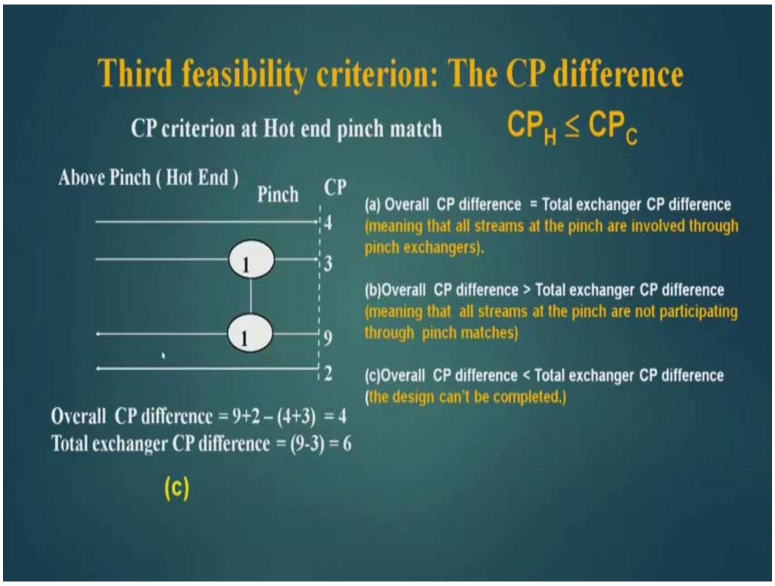

Now in this case, overall CP difference is more than the total exchangers CP difference. Now let us see a part c of this now, there are 2 hot streams and 2 cold streams and there is only 1 match so, the overall CP differences is 9 plus 2 minus 4 plus 3 is 4 and total exchanger CP difference is 9 minus 3 is 6. So, here the overall CP difference is less than is total exchanger CP difference so, we will saw there are three different result a, b and c.

Now, what we conclude out of this is, a where overall CP difference is equal to totally exchanger CP difference this means that, meaning that all the streams or the pinch are involved so, pinch exchanger. Part b, the overall CP difference is greater than, the total exchanger CP difference meaning that, all the streams at the pinch are not participating through pinch matches number c, overall CP difference is less than total exchanger CP difference, the design convert the completed.

Because, that convert matching between this and this so, here I have to do some cooling, here I have to do some heating. So, the design cannot be completed because, this matching cannot be done based on CP rules. Because, the criteria at hot pinch match is CP C should be greater than CP H or equal to, here cold is 2, hot is 4 so, cannot be matched. And if they cannot be matched, then either we have to do some splitting or we have to use utilities to cool down this and heat this and hence the design cannot be completed.

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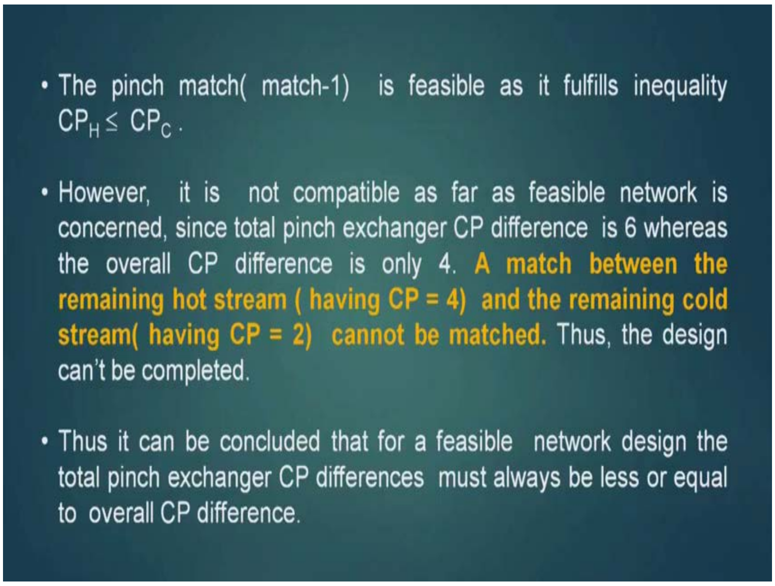

What we conclude, the pinch match, match 1 is feasible as it fulfils inequality. However, it is not compatible as far as feasible network is concerned since, total pinch exchanger CP difference is 6 whereas, the overall CP difference is only 4, a match between the remaining hot streams having CP's 4 and the remaining cold streams having CP 2 to cannot be matched. Thus design cannot be completed thus, it can be concluded that for a visible network design, the total pinch exchanger CP difference must always be less or equal to overall CP difference.

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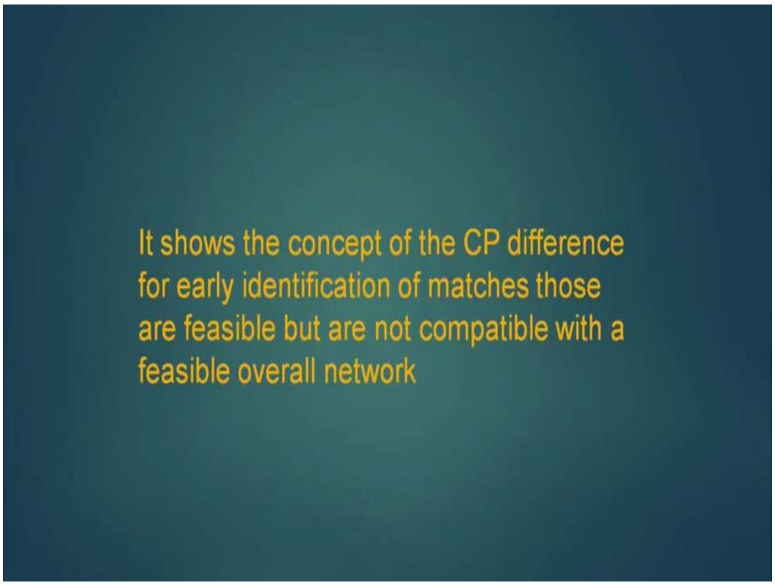

Now this example shows, it shows the concept of the CP difference for early identification of matches, those are feasible, but are not compliable with a feasible overall network.

Thank you.