Process Design Decisions and Project Economics

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Module - 5
Energy (or Heat) Integration of The process
Lecture - 26
Pinch Technology for Heat Exchanger Network Design

Welcome, in the 4th lecture of this module, the Heat Integration of the Process and today we shall see the Pinch Design Method for Heat Exchanger Network Design. In the previous, I introduced you to this method, after identification of the targets for heat exchanger network, we shall now start placing the matches between the process streams and pinch design methods is essentially the algorithm for that matching.

We said that, we shall demonstrate the pinch design method, using an example and for simplicity like for maintaining the continuity of this module. And using the exactly same data as used in previous lectures, that too hot and too cold streams and that data is appearing on your screen now.

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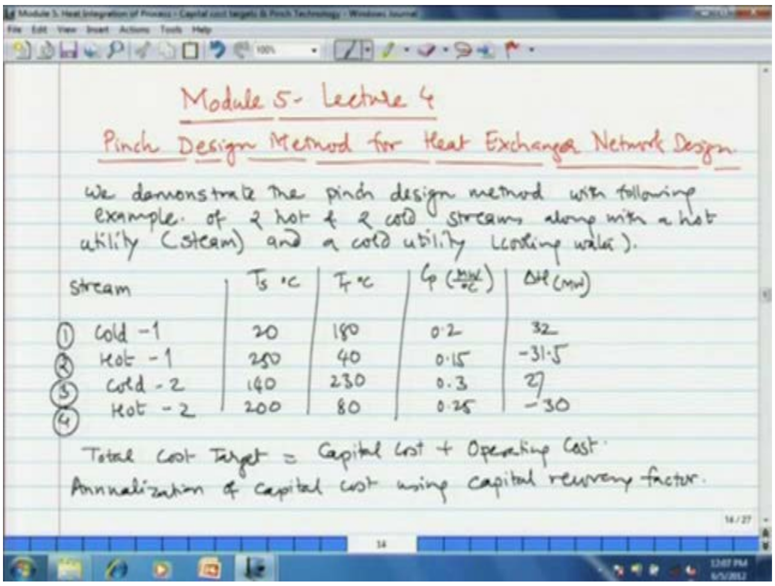

I had explained this earlier, the total cost target is the capital cost plus the operating cost and delta T min is the governing factor, that decides the tradeoff between this cost. Capital cost is the single time cost, which has to be annualized in order to add to the operating cost and in the module of economics process, with project economics, we have seen that, how we can do it.

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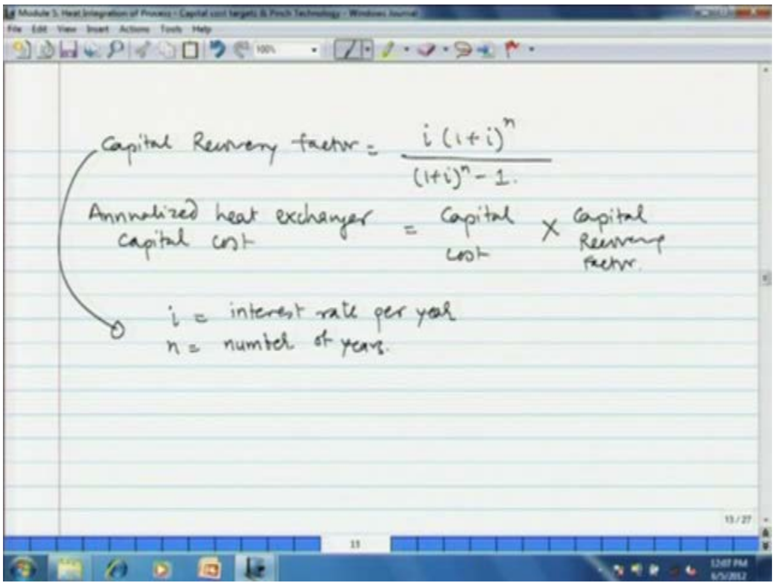

How, we can annualize the capital cost, it has to be done, using capital recovering factor, which is given as i into 1 plus i to the power n divided by 1 plus i to power n minus 1, where i is the interest rate per year and n is the number of years. So, the annualized heat exchanger capital cost, is the capital cost into the capital recovering factor.

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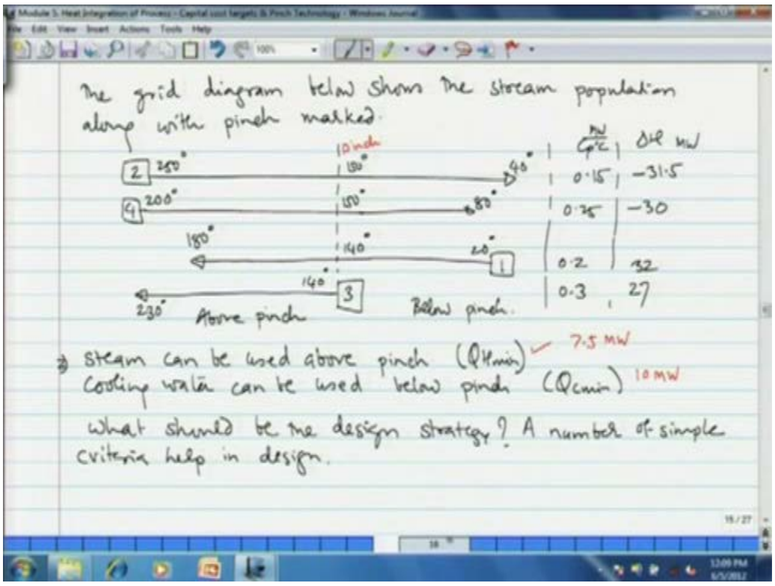

What I will do is that, I will demonstrate stream data in the form of the grid diagram, that is appearing on your screen. I have given the pinch in the dotted line, so this is the process pinch, the pinch temperature for hot stream is 150 degrees, for cold stream is 140 degrees, we have determined this, using problem table algorithm in the previous lecture. We have total of minus 61.5 mega waltz heat excess and we need 59 mega waltz of heats, for the heating of the cold streams.

We have 2 utilities stream and cooling waters stream can be used above pinch that Q h min. I have already determined and that was 7.5 megawatt and then cooling water can be used below pinched that Q c min. That we also determined as 10 megawatt in the previous lecture, what should be the design strategy. We have already identified and started one design strategy, in the previous lecture, that we shall start our design at the most constraint region of the problem, that is near the pinch.

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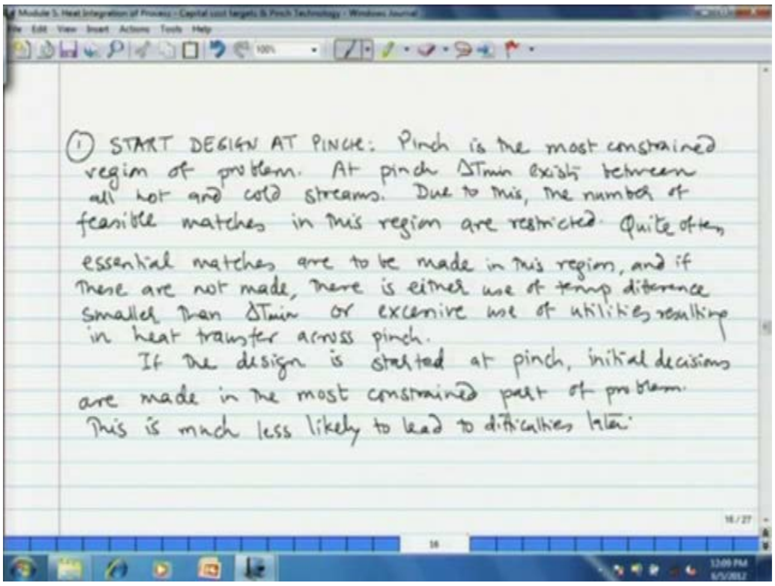

And in addition, we shall use some more criteria in to help us match, that streams without violating delta T min constraints. So, the first constraint that we already have introduced started design at pinch. Pinch is the most constraint region of the problem at pinch delta T min exist between all hot and cold streams and due to this number of feasible matches in the region are restricted. Quite often essential matches are to be made in this region before, we go for the subsequent matches or completely heat exchanger design. And if why is because this matches are not made for the constraint region.

There is either use of temperature difference smaller than delta T min, which is undesirable or excessive. Use of utilities which is also undesirable and both of these kind result in increase of the cost and we may also go for, the heat transfer across pinch which is prohibited. If the design of the started at pinch then the initial design, initial decisions are made in the most constraint part of the problem. This is less likely to lead to difficulty in meeting or designing of the network with given constraints later.

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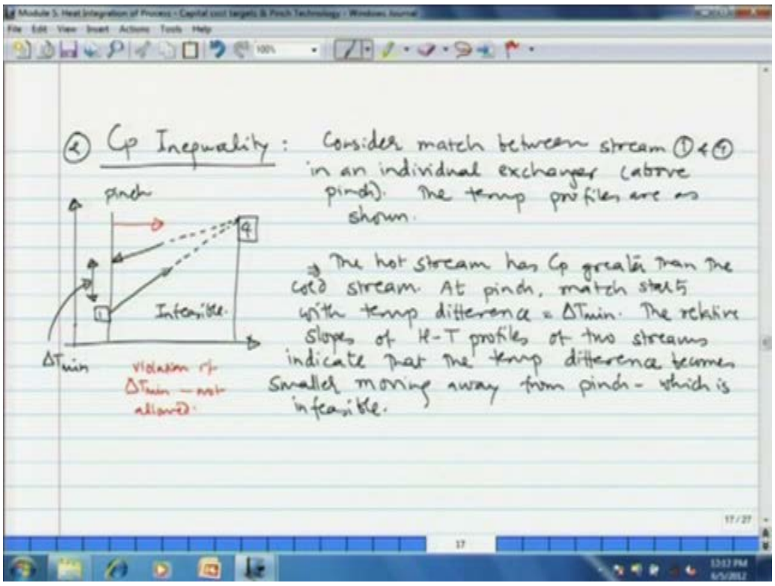

So, what is the first constraints, that is the C p inequality constraints, now I am again demonstrating the same thing with an example. Now at pinch both hot and cold stream is at pinch temperature, which is at 10 degree centigrade delta T min. Our constraint says that no heat exchanger will have temperature at different at any lesser than delta team in. That means, as heat exchange taking place hot and cold stream in a heat exchanger then the temperature different between them should increase. Now what I show here consider a match between one and four in an individual exchanger is above pinch.

What is the peculiarity about 1 and 4 steam, 1 has C p 0.2 and stream 4 hides C p as 0.25 and we are considering above pinch region. That means pinch region marking here red dotted. Now, since the hot stream has the C p greater than the cold stream at pinch the match start with temperature difference to delta T min and if you see the relative loops of H T profile of the 2 stream, which these indicate that the temperature difference become smaller as, we move away from the pinch. Now, here the steam 1 has C p lesser point 2 than steam 4.

So, because of lesser C p it is temperature will rise faster, than the reaction in temperature of steam 4 of higher C p and then. The temperature difference as we go away from the pinch means as the 2 steams are exchange in the heat exchanger is likely to reduce, which will reduce our which will violet our delta team in constraint. This is the violation of delta team in constraint and which is not allowed.

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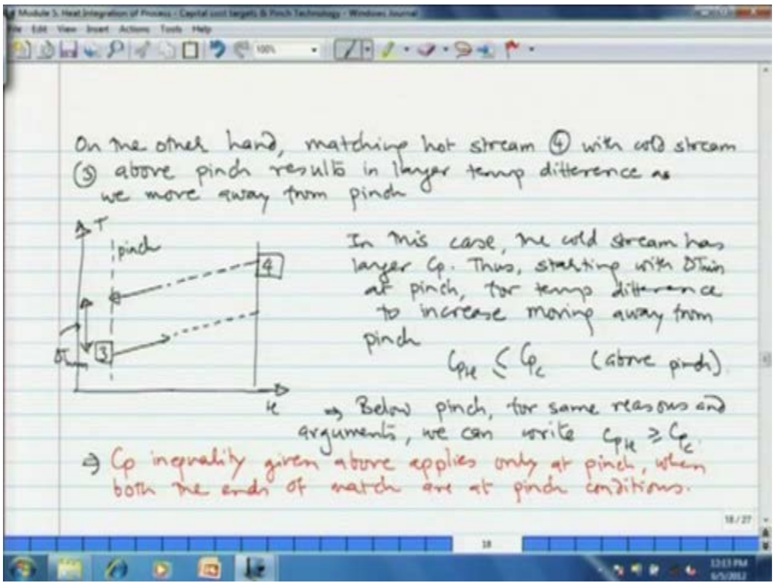

Therefore, we get one more constant placing matches between the exchanger is that, C p inequality should be obeyed which means above pinch. The hot stream should have C p value lesser than cold stream, which is now shown in the diagram, which appears in the screen now. On the other hand matching hot stream 4 with the cold stream 3, above pinch result in the larger temperature difference, as we move away from the pinch. If you match 2 with 3, we are matching stream 4 with cold stream 3 ((Refer Time: 07:30)), 4 has the C p of 0.25, 3 has the C p of 0.3, which means the cold stream C p has the higher than hot stream.

Therefore, the temperature difference is likely to increase, we go away from the stream that means, if we place the match with 3 and 4. The temperature difference at the left hand will be 10 degree centigrade with delta T min and at right end. Delta T will be greater than 10 centigrade, which is allow, which is permitted. Therefore, we get one constraint that above pinch C p h. The C p of the hot stream should be less than or equal to C p of cold stream.

Now we can make similar argument for below pinch region, for below pinch, for the same reasons and arguments, we can write C p h has to be greater or equal to C p c. However, we should note one point, that C p inequality given above apply is only pinch or region near to pinch as we go away from pinch. Then the temperature difference increase of in that case, we need not obey this particular constraint. So, C p inequality given at pinch the both ends are the matches are at pinch conditions.

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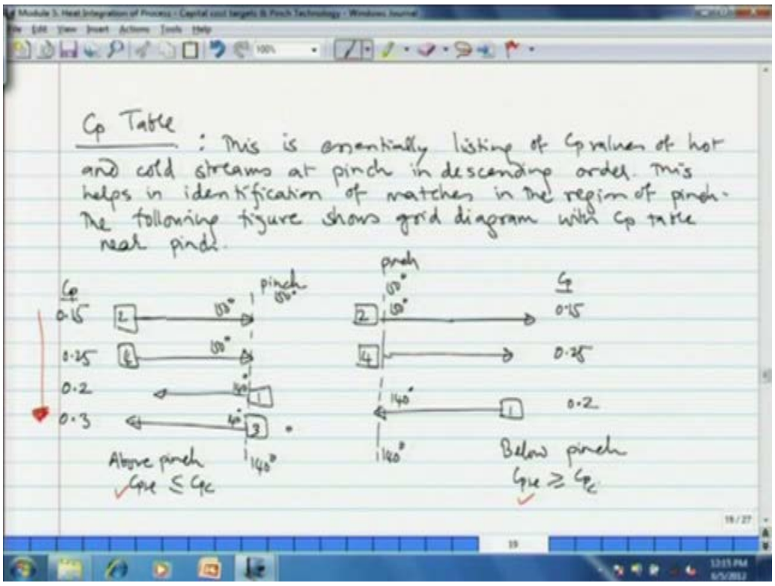

As we go away from the pinch that constraint is relaxed. Now, we have to make Cp table this is essentially, listing of C p values of the hot and cold stream at pinch in descending order. This helps in the identification of the matches in the region of pinch. And I am giving below C p table for the problem, at hand, the following figure shows great diagram for C p table near pinch. So, what we have done, we have listed all stream with increasing order of C p, above pinch C p h less than equal to C p c, below pinch C p h greater than or equal to C p c, so these are the constrains.

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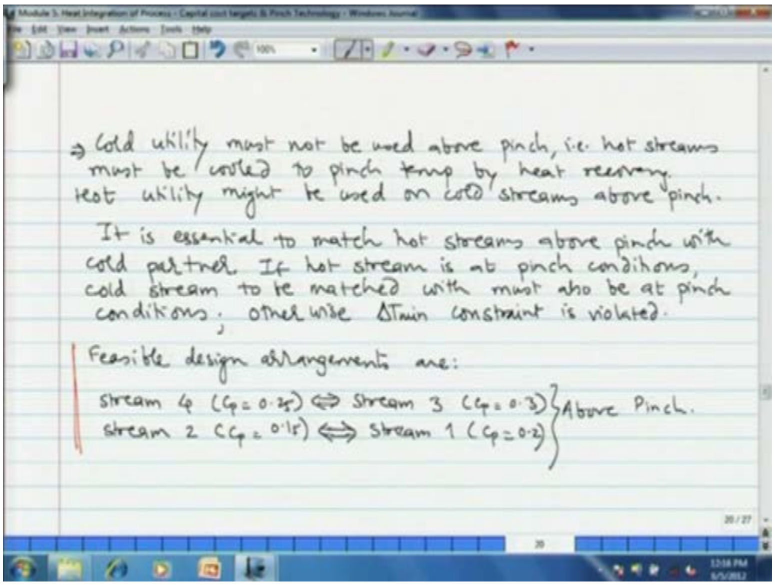

The next constrain is that of the number of streams, but let us see one thing before, we go ahead cold utility must not above pinch. That is all hot stream must be cooled to pinch temperature by heat recovery. In the above pinch region hot utility might use cold stream above pinch. To If they are not able to meet the temperature target. It is essential to match the hot stream above pinch, with the cold partner, if the hot stream is at pinch condition cold stream to be match with it must also be at pinch condition.

Otherwise delta T min constant is violated, then the feasible design arrangement with this constant, C p inequality constant is that stream 4 with C p 0.25 should be match with steam 3 with C p is equal to point 3 steam 2. C p is equal to 0.15 can be matched to steam one, which is C p is equal to point 2.

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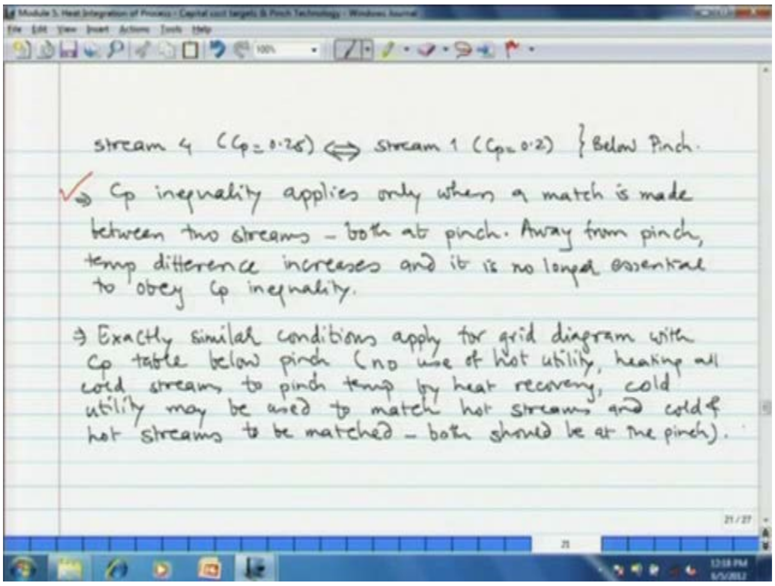

Then below pinch region stream 4 with C p equal to 0.25 can be matched with steam one, that C p equal to 0.2. Now this let us one stream, which is un matched in the below pinch region. That is stream, a stream 2 is not matched in the below pinch region and then we can use cold utility for that particular stream. C p inequality applies only, when match is made between the 2 streams between both at pinch. This is very important thing, which I already mentioned to you that C p, inequality applies for near pinch region, away from the pinch the temperature difference increases and it is no longer essential to obey C p inequality.

Exactly, Similar condition apply for agreed diagram C p table, below pinch no use of hot utility heating of all cold stream temperature by heat recovery. Cold utility may be used to match the hot stream and cold and hot stream should be matched both should be at the pinch conditions.

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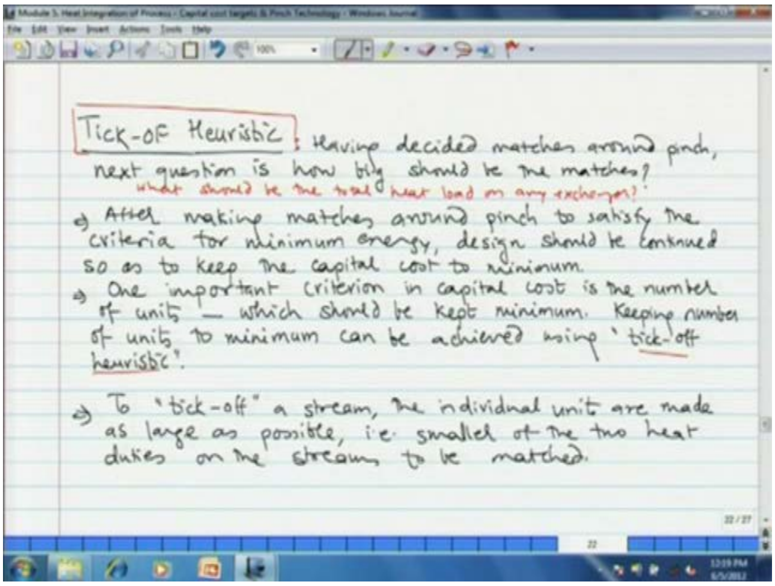

The next criteria, that we are going to see is that of tick off. Now this is related to the number of stream that, I just mentioned. Now once we decide the matches around the pinch like which streams have to be matched then the next question, that we have to answer is that how big should be this matches in other word ,what should be the total heat load on any exchanger, after making the matches around the pinch region to satisfy, the criteria for the minimum energy, designed should be continued.

So, as to keep the capital cost to minimum. One important criterion in capital cost is the number of units which should be kept at minimum keeping minimum number of units can be achieved as what is known as the tick off heuristic, what is tick off heuristic to tic of a stream. The individual unit is made as large as possible in that the smaller of the 2 heat duty on the stream to be matched, which means, that whenever we are matching 2 stream. Then the target temperature of either of streams should be meet, which means that stream goes of the design, which means the total heat duty in that particular stream is satisfied.

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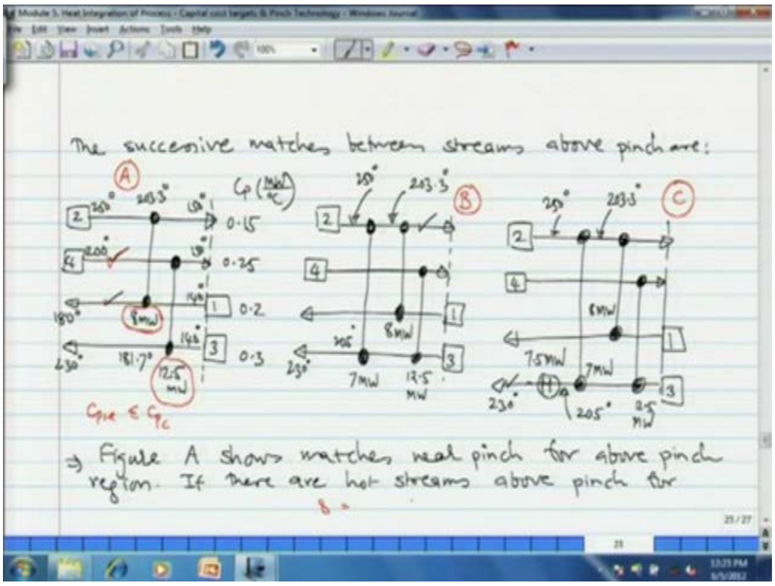

Let us see this particular constraint tick off heuristic with the same example, that we are working with 2 hot streams, 2 cold streams. Now, we are working at above pinch region, now we shall see how can successively place heat exchanger tick off particular stream. Now we have stream 2, the C p table and steam grade, that is now appearing on your screen. We have stream 2 4 1 and 3 all above pinch region. Now with C p inequality constraint, C p h should be lesser or equal to C p c constant, how we can place match stream 2 can be coupled with stream 1, that we have just seen.

And then the total heat load, total heat which is available with, stream 2 in the above pinch region is 250 150 into 0.15 that means, stream 2 has available with it 15 megawatt of total heat 250 minus 150 100.15 C p value. However, stream one requires only, 8 megawatt. Because, it as to be heated from 140 degrees to 180 degrees, that is 40 degree rise. It is C p value is 0.2.

So, 8 megawatt so stream 2 can easily give that much of heat to stream one and then we place a match and then place the heat exchanger of 8 megawatt capacity. And then steam 2 is ticked of which means heat duty on steam 2 sorry, stream 1 is tic off that means, total heat duty of stream 1 is satisfied. Similarly, we can match stream 4 with steam 3 as we just said due to Cp inequality constant.

The total heat available with stream 4 is 12.5 megawatt and the heat that is required for steam 3 is 27 megawatt. Now steam 4 can easily give all of it heats to steam 3 and then meet it is target temperature 150 and then we place the match, we place the heat exchanger capacity of 12.5 megawatt between steam 3 and 4. And then steam 4 is ticked off because it is temperature target temperature is meet after placing the steam.

Now, we have lot of heat left out in steam 2. So, what we do is that. So, we first calculate the exit temperature of steam 2, after heat exist the 8 megawatt heat exchanger between 2 and 1 steam 2 and steam 1 that can be done very easily. You can I leave that exercise to you we have 8 megawatt and 0.15. So, we can easily calculate the exist temperature steam 2 as it exist. The 8 megawatt exchanger, I leave that excise to you 8 megawatt is equal to Cp equal to 0.15 and at one end, we have the temperature of stream 2, that is 150 degree.

So, T minus 150 and then you can see that T is equal to 203.3 degree centigrade. So, that is the temperature of stream 2, when it exist the or when it enters actually, when it enters the 8 megawatt heat exchanger. Now we have already ticked off the 2 stream, and we have come significantly far from the pinch region.

So, the cp inequality constant is no more applicable, we still have 7 megawatts of heat left in steam 2 and steam 3, still requires about 14.5 megawatt of heat. Because, the total heat equivalent of the stream 3 above the pinch region was 27 megawatt out of which only 12.5 satisfied. So, stream 3 requires 14.5 megawatt. Now we can match steam 2 with steam 3, steam 2 has 7 megawatt of heat left all of that heat could be absorb with stream 3 and then we place a match this 7 megawatt heat exchanger. And that ticks off stream 2; that means, now stream 2 has given away all of it is heat to cold steams above pinch region.

However stream 3 still has not meet it is target of heat 230 degree, because only 7 megawatt out of 14.5 megawatt requirement has been given by stream 2. Now we can calculate the temperature of steam 3 as it exist, the second heat exchanger of 7 megawatt heat exchanger, That can be done exactly the same way as I explained before, that appears on the screen now.

That turns out to be 205 degree centigrade and now, we have absorb all of the heat from hot streams above pinch region to cold streams, we have no more, now heat surplus above pinch region. Now, therefore, surplus heat requirement of stream 3 can be met hot utility we still require 7.5 megawatt of heat on stream 3, which can be met with hot utility. And therefore, now we place the heat exchanger between steam 3 and hot utility stream which as the capacity of 7.5 megawatt and now the last stream, that is stream 3 is also ticked off. This means that in above pinch region, we have essentially 1, 2, 3 and 4 exchanger.

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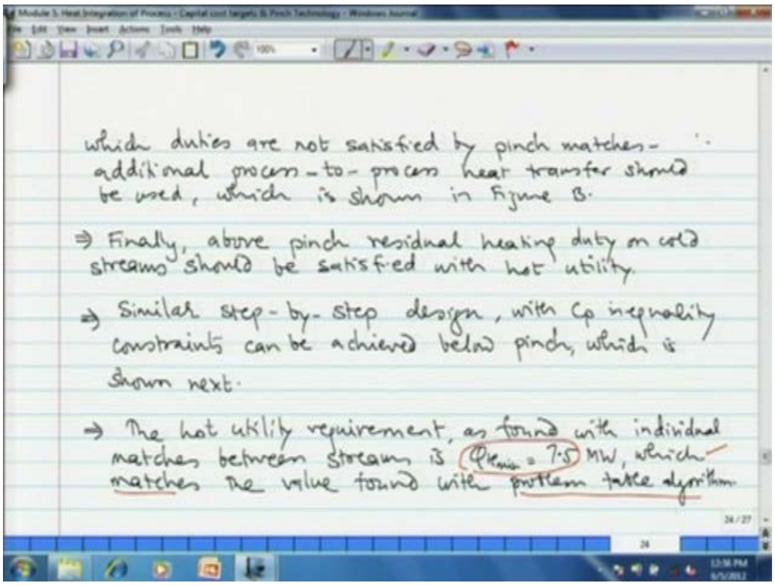

That was for above pinch region, similarly we can show a step by step design which C p equality constraint in for the below pinch region, which we see now. The hot utility requirement as found with the indicial matches between streams is given minimum equal to 7.5 megawatt and which are exactly the same as the value found with problem table algorithm in our previous lecture, so that point be note here.

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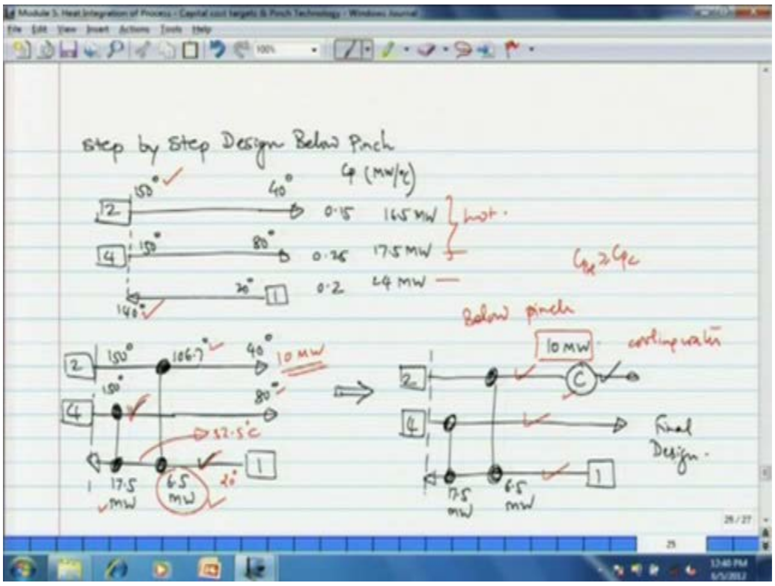

Now, we go for below pinch reason here, we see the step by step design, I had made a stream grade, thus the pinch or temperatures150 140 degrees, below pinch regions we had 3 streams 2 4 as hot streams and only one cold streams. Now which C p in equality constraint T h greater or equal to C p C we can match stream 4 with stream 1 and then again, we have to see that, which heat duties are high is lower streams 4 had 17 point megawatt available with it and stream ones required 24 megawatt.

So, all of the heat of stream force can be absorb in stream 1. So, that now stream 4 is ticked off, it meets it is target temperature of 80 degrees. But stream 1 still requires 6.5 megawatt of heat. The exits temperature of stream 1 as it comes out of the streams is 52.5 degree centigrade, which we can easily calculate. Using the same way as before, as we explain in for above pinch region and then we can place a match between stream 2 and 1. Stream 1 now requires only 6.5 megawatt of heat.

Because it has taken similarly 17.5 megawatt of heat from stream 4 and it has the temperature of 52.5 degree centigrade, now after giving away 6.5 megawatt of heat to stream 1. The stream 2 has still left with 10 megawatt of heat and then you temperature of stream 2 as it exist the 6.5 megawatt exchanger is 106.7 degrees centigrade, determined in the same way as before. And now we do not have any cold stream left, because there was only one cold stream below pinch region, which had a heat requirement of 24 megawatt, which has been met 17.4 megawatt from stream 4, 6.5 megawatt from stream 2.

So, 1 is now ticked off, now whatever heat is now left, with whatever 10 megawatt heat is left with stream 2 can now only be absorbed in cool utility. So, we have to use cold utility below pinch. Now and replace the heat exchanger between cold utility, that is cooling water and the stream 2 and the here. The capacity of this heat exchanger is 10 megawatt.

So, that completes the design with placing of other heat exchanger between cold utility and stream 2. The stream two is ticked off, now all 3 streams are now ticked off and the design is now complete. The couple that total design is essentially amalgamation of design above pinch for region and below pinch region and above pinch region.

We just saw that we needed ((Refer Time: 24:12)) total 4 exchangers. And below pinch region, we need 1 2 and 3 exchangers.

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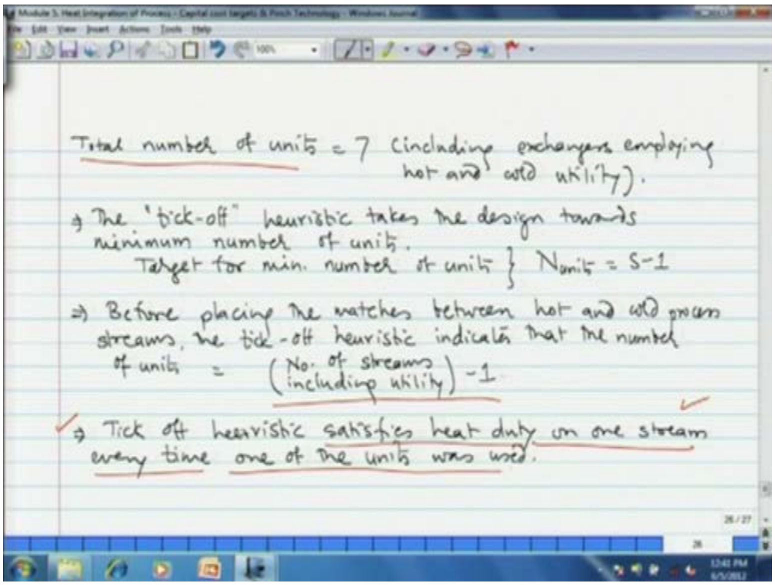

So, the total number of exchangers, totals number of units of need, are 7 including exchanger, employing hot and cold utility. The tick off heuristic side designs towards the minimum numbers of units, when you used the graph field, we found that the minimum number of unit was S minus 1 and this, what we seemed to achieved exactly. For above pinch region ((Refer Time: 24:49)), we had totally 4 streams and 4 stream plus hot utility. So, total 5 streams and we ended up with 4 exchangers for below pinch regions.

We had total 3 process streams plus cold utility. So, 4 streams and we ended up with 3 exchangers. So, the total number of exchangers in the entire heat exchanger network here are 7. So, tick off heuristics has taken the design towards the minimum numbers of unit as predicted from the graph theory before, placing of the matches between hot and cold process streams. The tick off heuristic indicates that the number of hot, the number of units are equal to number of streams including utility minus 1 and needless to mention.

Now, but I am repeating for a convenience a that tick off heuristics satisfies heat duty on 1 of the streams every time, when 1 unit was used and that is why it gives us the minimum number of units.

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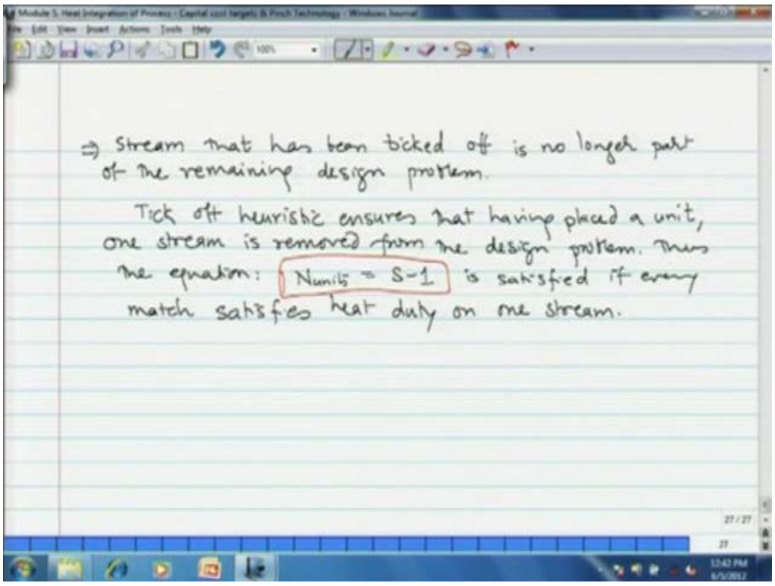

The stream that has been ticked off no longer, the part of the remaining design problem and thus the tick off heuristics ensures that having place to unit 1 stream is removed from the design problem. And then we achieve the target number of minutes equal to S minus 1.

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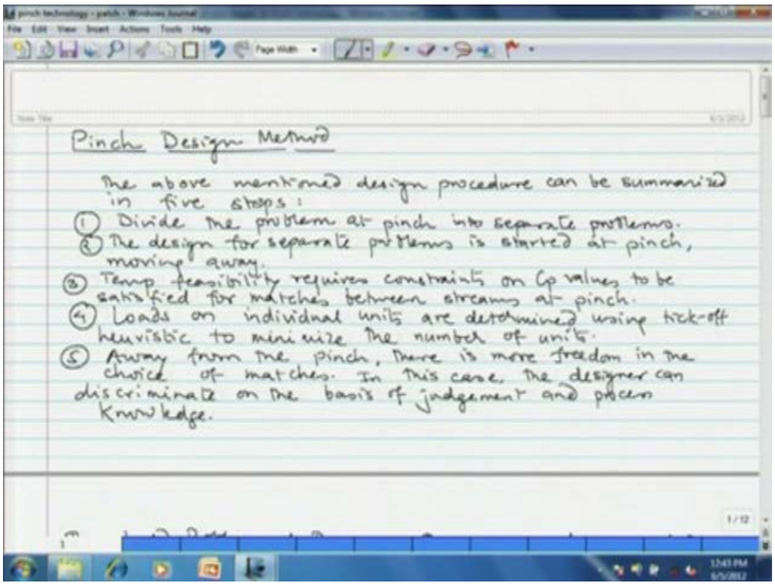

Now, we summarized the algorithm of pinch designed method the above mentioned design processer can be summarized in five steps. First is the division of the problem at pinch into separate problems or separate regions, than the design for separate regions above pinch and below pinch is the started at pinch and then slowly. We move away from the pinch. The temperature feasibility requires constraint on C p values to be satisfied for matches between streams at pinch C p h less than equal to C p C above pinch and vice versa. Below pinch, the loads on individual units are determined using tick of heuristics to minimize the numbers of units.

Away from the pinch, there is more freedom in choice of matches. Because the C p in equality is not mandatory as we move away from the pinch and this case the designer can discriminate on the basis of judgment and problem knowledge.

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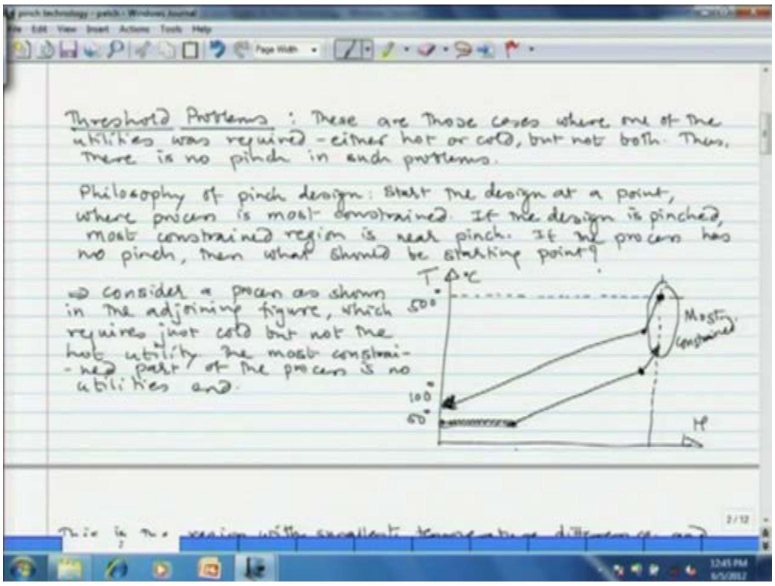

Now let us see some special cases and these are the threshold problems, we had already seen threshold problems in previous lectures. Threshold problems are those problems in which, this the temperature for the enthalpy matched at one end of the problem. That means, you do not required either hot utility or cold utility, like one which you see on the screen now, is that one which requires no hot utility, which means all temperature requires temperatures of cold streams, are met with heat absorption from hot streams.

The philosophy of pinch design is that started design at a point, where the process is most constraint. Now, in case of thresholds problems, there is no pinch therefore, how we can determined the starting point. If the design is pinch the most constraint region is near pinch with the process has no pinch, than what should be the starting point now. I have given an example on the screen which, where you have one, where you have basically no hot utility requirement. But, only the cold utility, but must constant part of the problem is the no utility ends like this, the most constraint part of the problem, in the other hand you have cold utility, which you can vary.

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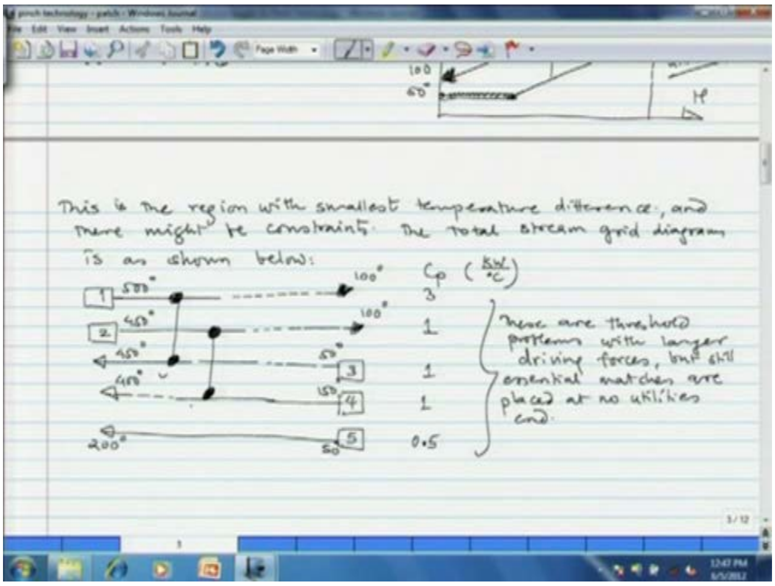

Until what we find is that the most constraint region is the region with, the minimum temperature difference like. If you see the temperature difference in these regions, we have the minimum temperature difference between the two composites streams at the hot end problem and the most constraint region. And then we start our design at that point that mean, we start our design at the point of no utilities end, that no utility end design. The hot end and now you can see here, placing out the matches the C p table.

This is the region with smallest temperature, difference the hot and there might be constraints. There is the total grid diagram is as shown, we first make a match between stream 1 and 3, we have total 3 cold streams and 2 hot streams. The temperature are also shown and then finally, we see that the all the there is no hot utility requirement as such and then these are threshold problems with larger driving process. But, still essential matches are placed at no utility design, so we place to two matches at to utilities.

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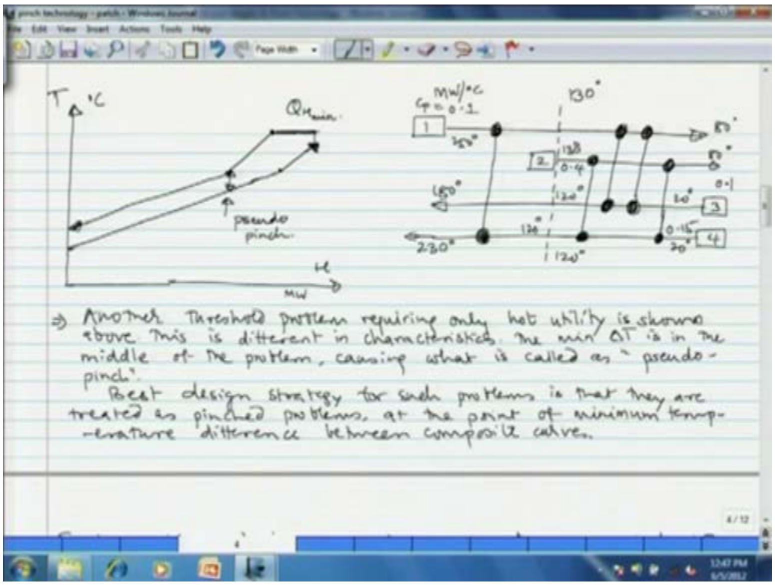

We see another that was problem with no hot utility.

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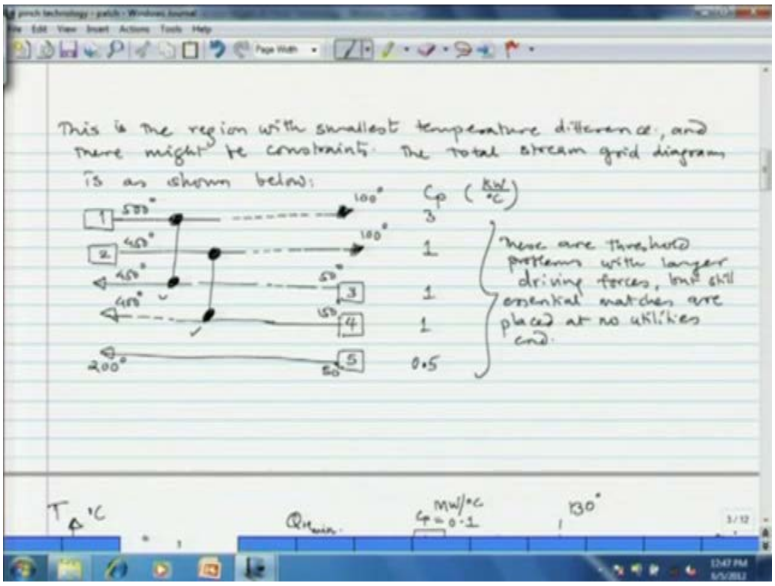

We shall see another problem with no cold utility here no cold utility, I have also the given the greed diagram for the streams we have total of 2 hot streams. And 2 cold streams and temperature are also given, and then we can make essentially, the matches as I have shown in the very much same as way we did for the previous design. Than we shall see we said the best design statergy, first such problems is that, they are treated as pinch problem, at a point of minimum temperature differences between the composite curves.

That the 2 composite curves are as shown and we shall monitor. The temperature difference between this 2 composite curves at different point at different enthalpy interval. And where the temperature difference becomes minimum, it turn to be delta tica min. It may be higher than delta tica min, but along all enthalpy track the temperature difference becomes minimum at this particular point. So, what we call this point is single pinch and the best designer stagey, for a such problem is they are treated as pinch problem and all point of minimum temperature, difference between the composite curves. And then the design starts and then we move away slowly from the temperature from the pinch point or assume the pinch point.

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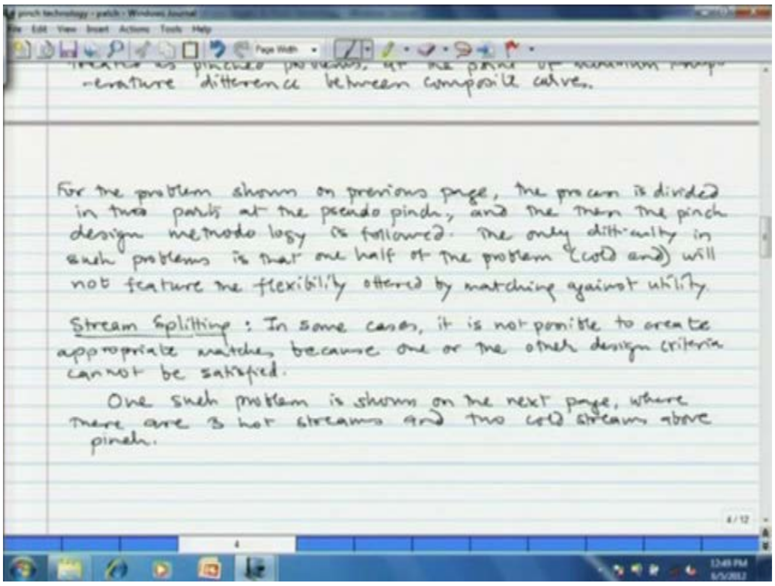

So, this problems are very must similar to that, we have seen which has a pinch. The same designed the methodology can be followed for this such problems. However, only difficulty in the such problem is that one half of the problem, that is cold and you will not feature the flexibility, which is offered by matching against the utility. Now let us see one peculiar aspect of pinch designed for heat exchanger network, that is streams splitting in some cases, it is not possible to create appropriate matches. Because, 1 or other created design criteria not can be satisfied and one Such problems is shown here, where we have 3 hot streams and 2 cold streams above pinch reasons.

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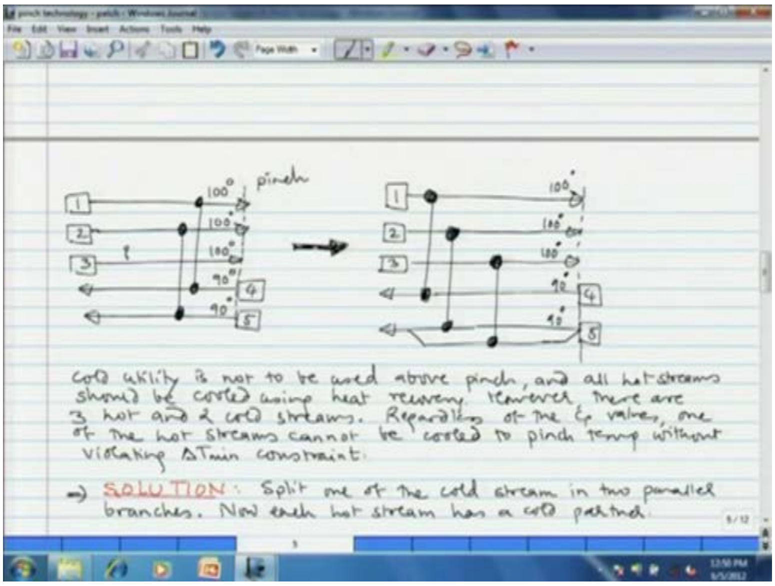

If pinch had to follow the take herustick, than we can place 2 matches which will take of either hot or cold streams. But, we shall still be left with one hot stream for which, there is no match matching cold stream.

Now how do we cool this particular like in this particular case. The stream 3 has no cold partner in this case, how we can make a match for stream 3, we cannot use cold utility above pinch. Because, that will violate our constant the basic constant and it will be the increasing operating curves. So, the only solutions, for such problem is that a way split one of the cold streams into 2 parallel branches.

And now each of the hot stream has the cold partner and now and that particular split stream designed is shown on the right hand side of your screen. We are splitting stream 5 the one which has a higher C p, that is split and then make 2 types of little streams and then we have basically, partners for all 3 hot streams cold partners for all three hot streams.

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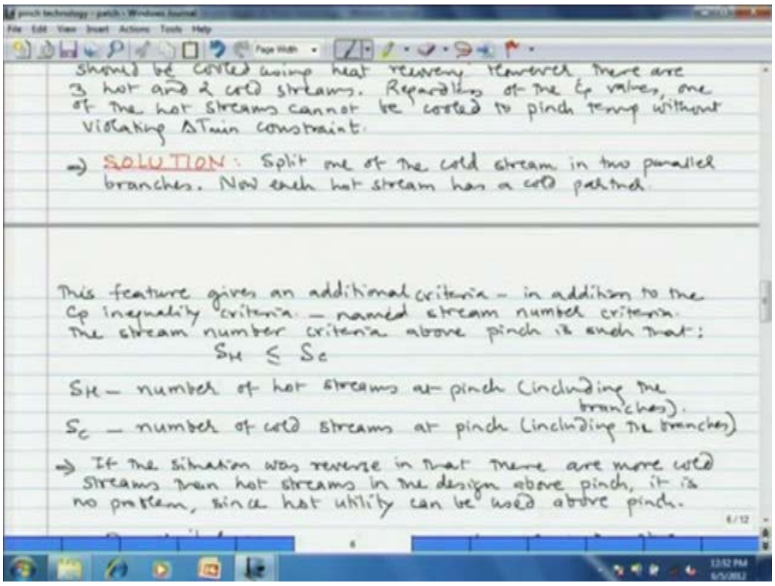

Now this picture gives an additional criteria for designing for network in a addition to the Cp equality and stick of huresetic criteria and that in terms of streams number. The stream number criteria, the stream number criteria above pinch is such that S H is less then equal to Sc. Sc is the number of hot streams at pinch in the above pinch reason, should be less or equal to number of cold streams at the pinch.

Including the judgment, including the splity, if the situations was reversed in that there is more cold streams and hot streams in the design above pinch in it is no problem. Because, we are allowed to use hot utility above pinch reason, show if a cold stream does not have a partner in the above pinch reason, we can match that cold stream with hot utility, how similar reasons one can argue, that the stream population constraint for below pinch region should be S H greater or equal to S c.

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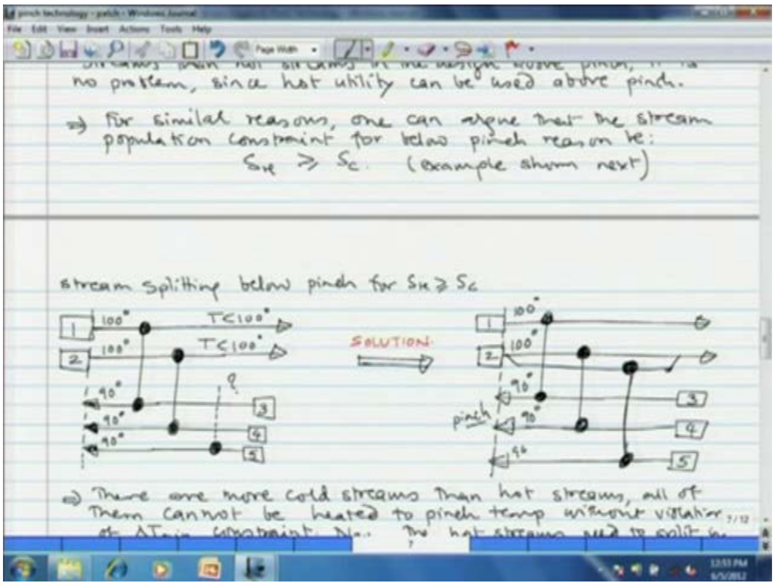

So, all cold streams should have hot partners, if any hot streams does not have the cold partner, that can discrete on see can be met with cold utility. Now I am showing the similar situation here, we have here 2 hot stream below pinch regions and 3 cold streams, now after matching 2 pinch units.

Now, after matching 2 units tica of huresitics table is left with ne cold stream, we cannot use the hot utility in the below pinch region and to take care of this problem. The solution to this problem is that, we split the hot stream with high C t value in 2 parallel streams and the branch of stream 2 is matched with stream 5, which did not have the partner hot partner.

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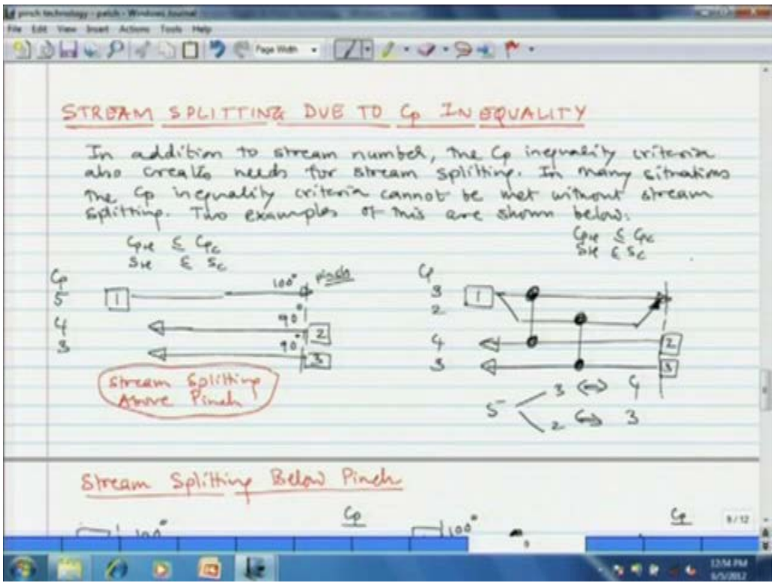

Again if, there are more hot streams then cold streams in the below pinch regions, we have no problem, because we can use hot utility in the below pinch region. The stream splitting could also be required, because of C p in equality and one such problem is shown on the screen now.

Let us say we have 2 hot 2 cold stream in the above pinch region and one hot stream. Now this is as far as the stream, the stream population constraints Sc is concerned that is satisfied, but we have another constraints of C p h is less than or equal to C p c. Now look at the C p value of the stream hot stream has the C p value of 5 and 2 cold streams has the C p value of 4 and 3.

So, none of the hot stream, one of the cold stream has C p value, sufficiently high to be matched with the high stream and now, if we place the match randomly then we are likely to violate the delta t constraints. Now what we do the solution to this problem is that we split stream 1, into 2 parallel streams and the C p value here is the split streams here are 3 and 2. So, C p value 5 is split into 3 branches C 3 and 4. Now these 3 branches are matched with the streams 2 and 3.

Because, the first branch with C p is equal to 3 is with C p equal to 4, so the C p constraints is obeyed and then second branch of 1 with C p is equal to matched with the cold stream with C p is equal to 3. So, that constraint is also obeyed. So, that means, stream splitting may be required, because of C p inequality.

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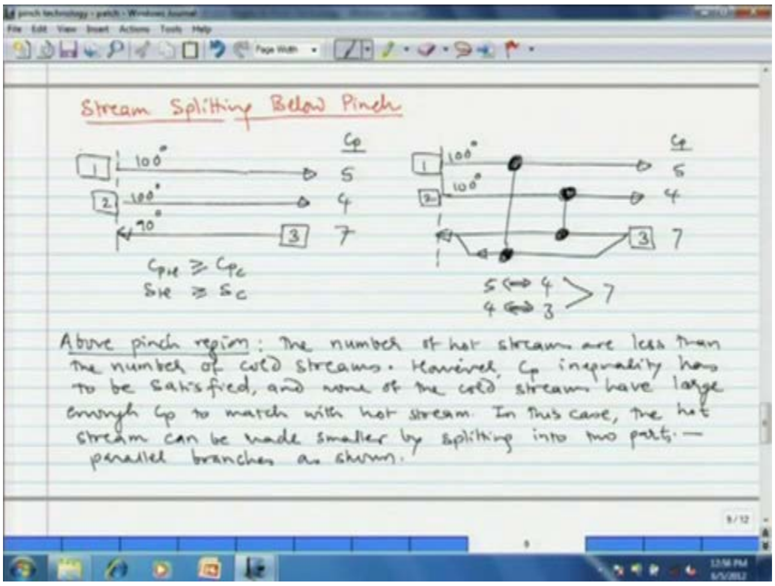

Similar situation is shown for below pinch region now, we have for below pinch regions 2 hot streams and 1 cold streams. So, as far as only stream constraints is concerned S H greater or equal to S c, this situation is ok. However, we have problem of C p inequality the cold stream has the C p of 7 and 2 hot stream has the C p of 5 and 4. Now none of the of hot stream C p is high, enough to be matched with the cold stream, because we have the C p constraints and that C p H should be greater or equal to C p c.

And none of the hot streams has C p is high enough to be matched with the cold stream, now what we do is that, we split the cold stream into 2 branches. The C p 7 is split into 4 and C p 3. And these 2 branches matched with the hot streams like, the 1 with C p is equal to 4 is matched with stream 1, C p equal to 5 and the1 with C p equal to 3 is matched with C p equal to 4. And therefore, we have the constraints of C p h is greater or equal to C p c satisfied.

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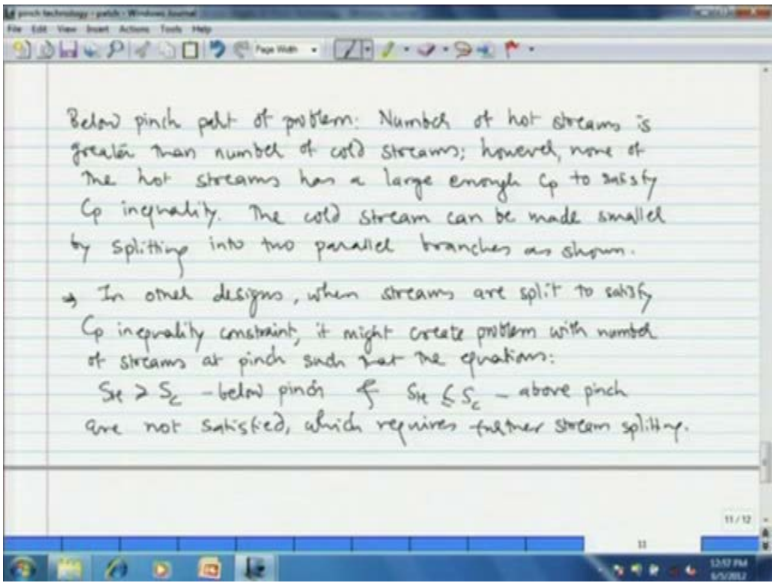

In some other design problems, where the streams are split to satisfy, C p inequality constraints. It might create problem with number of streams at pinch such that the equation S H greater than or equal to S c below pinch and S H is less or equal to S c above pinch region are not satisfied, which may require further splitting of the streams. The stream splitting adds another degree of freedom in the design. For example, we have split the streams into 2 like for example ((Refer Time: 40:12)).

In case of above pinch region, we had split the hot streams, we had split the hot streams with 2 branches with C p value 3 and 2. But it need not be 3 and 2 like the split into branches could be 4 and 1 and then which still satisfies because we have C p at lesser or equal to C p c. We have one cold stream with C p equal to 4. So, this is C p equal to 4, it is still obeying the C p constraints. So, the split could be 4 and 1, it could be 1.5 and 3.5 say like that.

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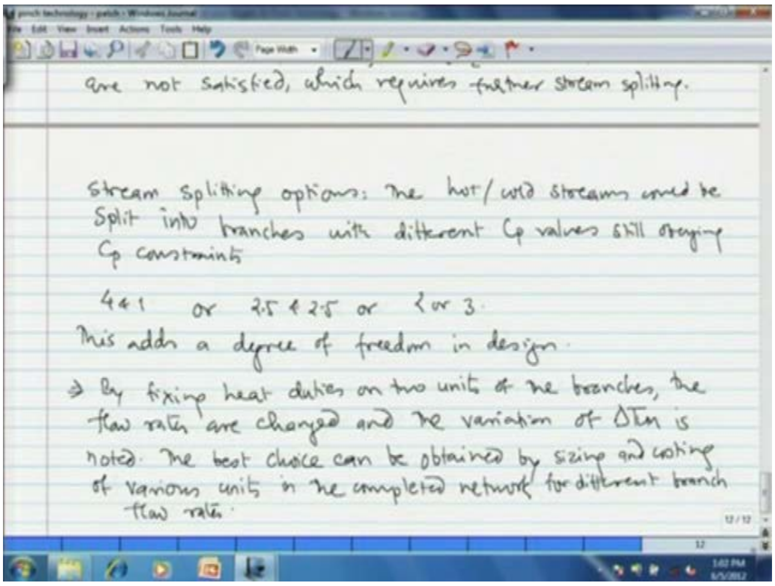

So, the splitting of stream adds the degree of freedom, that point we note stream splitting options. The hot or cold stream could be split into branches with different C p value, still obeying the C p constraint like in the first example. That we saw we could have the C p value four and 1 or 2.5 and 2.5 and all of this could have obeyed 2 or 3 criteria so on and so forth.

This adds the degree of freedom in the design. Now how do we choose between them between these options, we will fix the heat utilities on to units and change the number branch durates and temperature, difference across each is changed. The best choice can be made by sizing and costing of the things in various units of completed network for different branch units. So, that point we note by fixing the heat duties on to unit of the branches the flow rates or C p value are changed.

And the variation of temperature variation of delta T lm is noted the best choice, can be obtained by sizing and costing of various units in the completed network, for different branch flow rates. Now, we shall show this particular pinch technology algorithm in the form of the flow chart.

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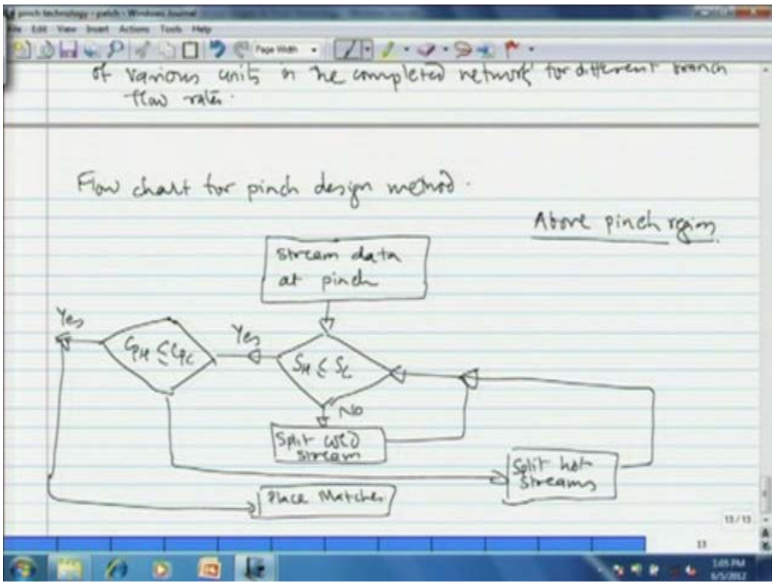

You have the stream data at the pinch, then you have to first see that the stream population criteria is satisfied S H, less than or equal to S c for above pinch region, this particular chart is for above pinch region. If it is satisfied then you have to check the C p in equality constraints C p h less or equal to C p c constraints. And if that is also satisfied then you have to go and place the matches.

Now, if the stream population is not satisfied then you have to go for splitting of cold streams and then once again go and check whether, the C p h and C p c, the stream population criteria in C p inequality criteria is satisfied. If the C p inequality is criteria is satisfied after the splitting of cold stream, then you can the cold stream matches.

However, if that is not satisfied, then you have to go and split the hot streams. And once again check whether the stream population criteria is satisfied and then the whole algorithm follows, then the stream population is satisfied, then you have to see the C p h is less or equal to C p c criteria. Again it is satisfied then you place the matches or you repeat. This is like the algorithm for above pinch region.

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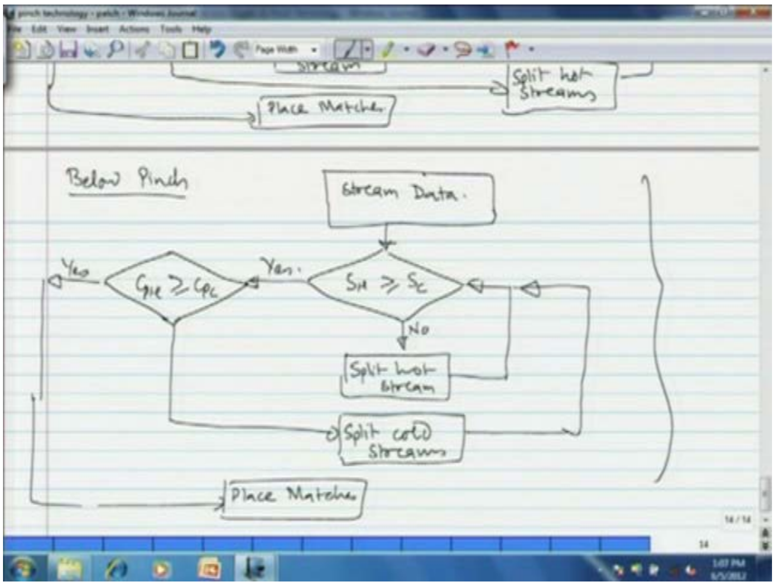

We can write the similar algorithm for below pinch region, you start with the stream data, then you check the stream population criteria whether S H is greater or equal to S c is satisfied. If that is satisfied, then you check the C p inequality criteria that is C p h greater or equal to C p c, if that is also satisfied which is the luckiest equation. Then you can go and place the matches. In case where the stream population is not satisfied, then you have to go and split the hot stream and once again check whether the stream population criteria satisfied then C p criteria is satisfied.

And then if that is done you place the matches, now let us say after splitting of hot streams the stream population is satisfied. But the C p inequality is not satisfied then you have to go and split the cold streams and then once again you have to check the stream population criteria and then C p inequality criteria and then go and place the matches.

These are the 2 flow sheets which summarize the pinch technology algorithm, that we have seen in today's lecture. This brings us to the end of this module, that is heat integration of the process, we have the tutorial section of this module in which we shall apply all the principles, that we have learnt in this module. The principle of composite curves, the principles of algorithm principle of delta T min and then the pinch technology network design, network from that we have learned today for different problems.

Thank you.