Process Integration
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Module – 7
Tutorial & Case Studies
Lecture - 2
Problem Solving Using HINT Software - Part 02

In this lecture, we will see how to do cost targeting, we have already demonstrated the area target using the data available in table number 3.

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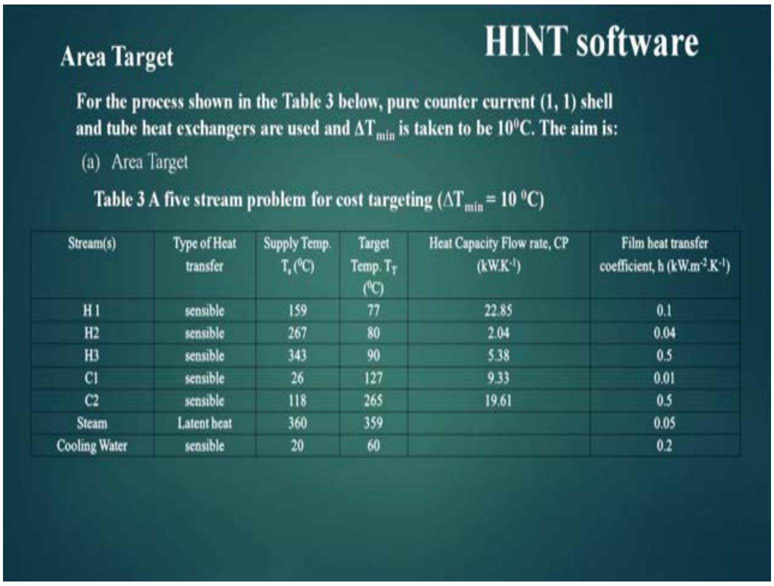

Now, was this problem? Let us see how to do cost targeting? We introduce the stream data H 1 supplied temperature is 159, target temperature is 77 and m C p value 22.85. Second stream, H 2 supplied temperature is 267, target temperature 80 and m C p value 2.04. Third stream H 3 supplied temperature is 343, target temperature 90 and m C p value 5.38. Fourth stream is C 1, supplied temperature 26, target temperature 147 and m C p value 9.33. The fifth stream is C 2, supplied temperature is 118, the target temperature is 265 and m C p value is 19.61.

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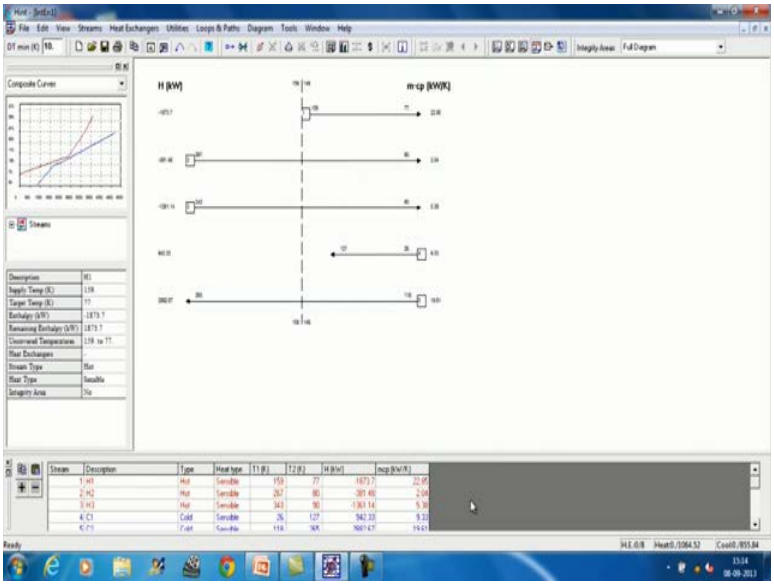

So, this completes my stream table which is shown in lower part, we can match the temperature. Now, this is time to input the other data of the area targeting, so we go to area targeting. The heat transfer coefficient of the first stream is 0.1; heat transfer coefficient of the second stream is 0.04. Heat transfer coefficient of the third stream 0.5, heat transfer coefficient of the fourth steam is 0.01 heat transfer coefficient of the fifth stream is 0.5.

Now, we introduce the heat transfer coefficient of the utilities, the first utilities which is the heating utility, heat transfer coefficient is 0.05. The second utility it is the cold utility, heat transfer coefficient is 0.2, this finishes the heat transfer data, so now we go to the utility data and go for add thus you have to define the user defined utility.

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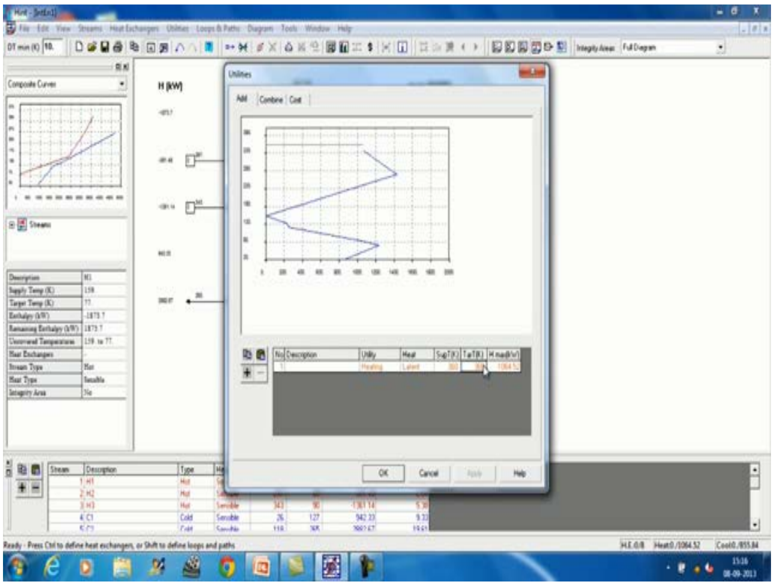

We place here plus, then we put here data 360, the temperature supply, temperature of the hot utility and here 359, then again press plus. You have to define the cooling utility, cooling utility temperature is 20, this temperature is 60. So, here we see that the both these utilities are been defined you can say.

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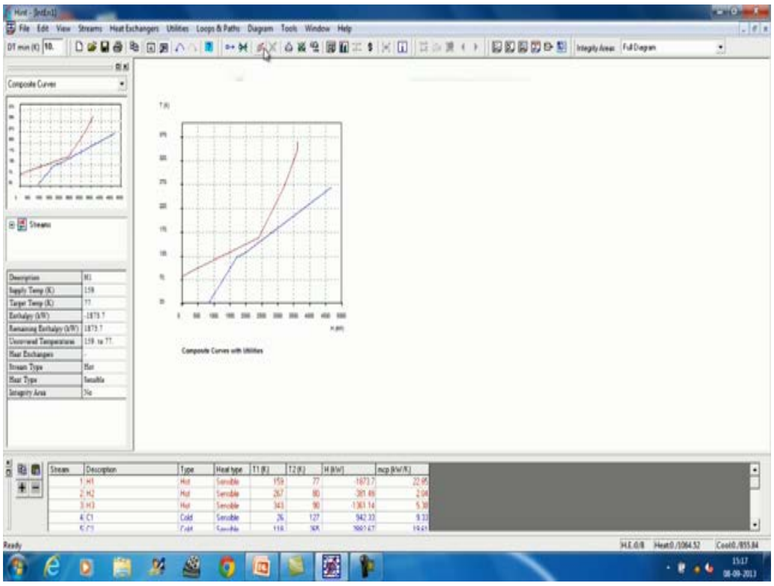

Now, we can see the composite curve with the utility, we are not added the utility that sight as that is not coming we go for the combine, now we can combine the hot utility. So, this is the hot utility to showing and similarly we can combine the cold utility, this is the cold utility and this is the hot utility we can say. So, it shows that the user defined utility completely satisfies the energy requirement of the process. Do you want to show these utilities instead of the default utilities? We say yes, now it shows composite curves with utility.

We can see from here, the composite curves of the utility, now the problem is well defined. Now, we can go for the area target, we see the area target is given as this; we can define here the heat transfer coefficient we type as to be. So, the heat transfer coefficient is 0.5 here and the second is 0.2, we say yes ok. The area target, now the value of the area target is 4008.77, now area target is completed, then we can go for the cost targeting in which we have to give the cost data.

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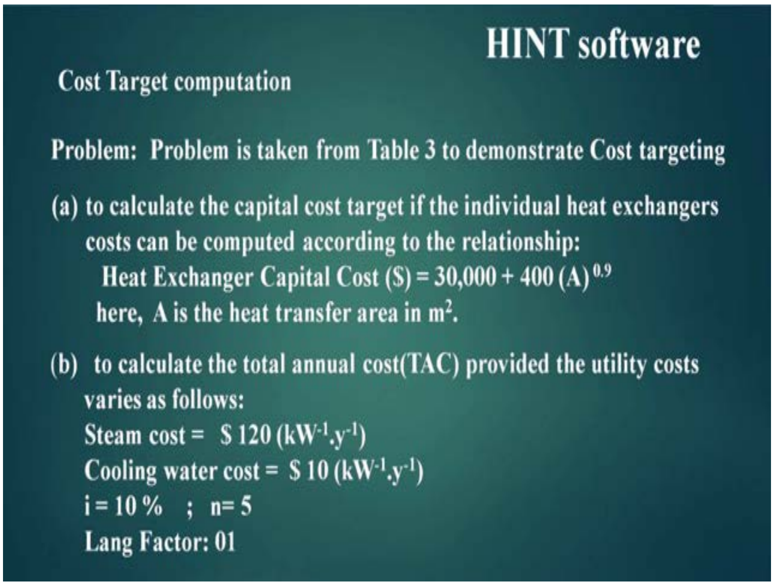

This is cost data which we will fit to the program it to calculate the capital cost target, if the individual heat exchanges cost can be computed according to a relationship. It keeps you a relationship for the computation of capital cost and that relationship is 30,000 plus 400 into area to the power 0.9. Here, A is the heat transfer area in meter square and to calculate the total annual cost, the fix costs as well as operating cost are required.

So, that is two utilities one steam and other is cooling utility that is called water. So, you have to provide for the cost so steam cost is dollar 120 per kilo watt per year and cooling water cost is dollar 10 per kilo watt per year. Interest rate is 10 percent, number of years that is effective years for the heat exchanges, which is life of the heat exchanger is taken n is equal to 5 and Lang factor is taken as 1. So, details of this then we seen in any economic computation where the economic computation is given in any book. How the Lang factor is used or how the interstates are being used for the computation of differentiation values?

So, using this data, now you can compute the cost, so to compute the cost we go to against stream cost data. Here, payback period is 5 years, according to our problem, interest rate is 10 percent and Lang factor is 1. Now, from the stream number one the data is 30,000 and this is 400 and this factor is 0.9, this is the cost equation that is cost correlation C is equal to A plus p A to the power C. So, in our case A is 30,000, our case b is 400 and c is 0.9, similarly for stream number two again in our cases is 30,000 this is 400 and this is 0.9.

For the third stream also, we have this is 30,000, this is 400 and this is 0.9 for the fourth stream also this is 30,000, this is 400 and this is 0.9. Now, you can have different cost correlations for different eat exchanges, here we assume that the all the heat exchanges are in the same area range and made up of same material. In actual fact, the heat exchanger may be made up of different materials and their area range may be different.

So, this value is 30,000, 400 and 0.9 may change for definite structure, here to give you an example we have taken the same cost equation for all the heat exchangers. In actual, this may not be true, fifth stream is 30,000, 400 and 0.9, now we go for the utility. For the utility also, we have assumed that the heat exchanger of cost can be computed in the same cost relationship that is 30,000 here, 400 here and 0.9 here.

Our utility number two is again 30,000, this is 400 and this is 0.9, now this finishes our fix cost computation part. On the computation we have seen how to feed the cost data to calculate the fixed costs of the heat exchangers. Now, to find out the total annual cost the operating cost data as also to be failed in the program in the operating data, the cost of the steam and the cost of the cooling water as to be careen.

So, this is the operating cost data, in this part utility number one is the hot utility, now here we filled the data that is 120 dollars per kilo watt per year and the utility number two is the cold water the value is 10 dollar per kilo watt per year. Once we fill this two data, we have complete data available here with us that are operating cost is 1, 27, 742 dollar per year. The capita cost is 2, 68, 905 and total cost is 3, 96, 648, once we have completed this, now we have the cost targeting value. Now, this cost targeting value, the cost targeting value will change with 1, 230 minimum.

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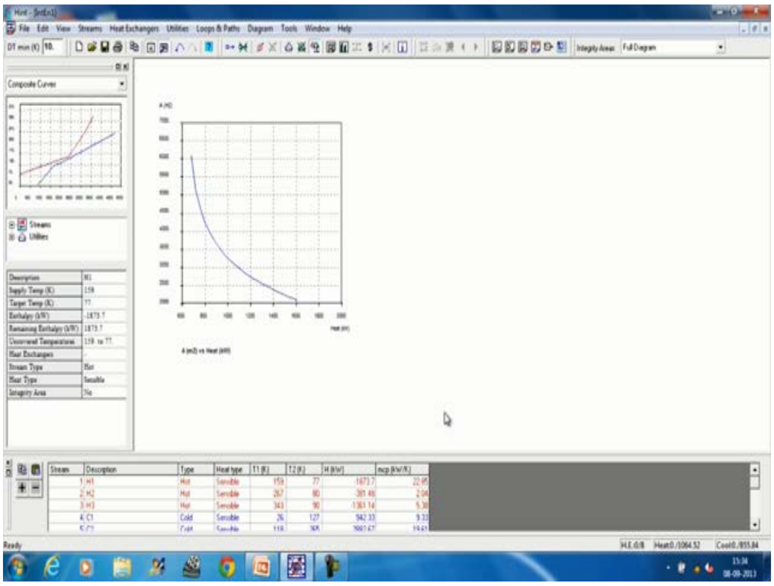

So, the next step two, see what happens when delta T minimum is changed and what is this effect of the change of delta T minimum on energy target, on area target, on pinch temperature, on minimum number of heat exchange and cost target. We will also see the variation above our parameters and the effect of heating consumption on the total area of network. So, we can go to the diagram, we can go to the delta T minimum analysis, we can go to the energy target, it says that what is the minimum value of delta T minimum you want to take. Here, we have taken it to be 1 and the maximum value we have taken and to be 50 and we want to generate 50 number of points in between, that means almost the addition is of 1 degree.

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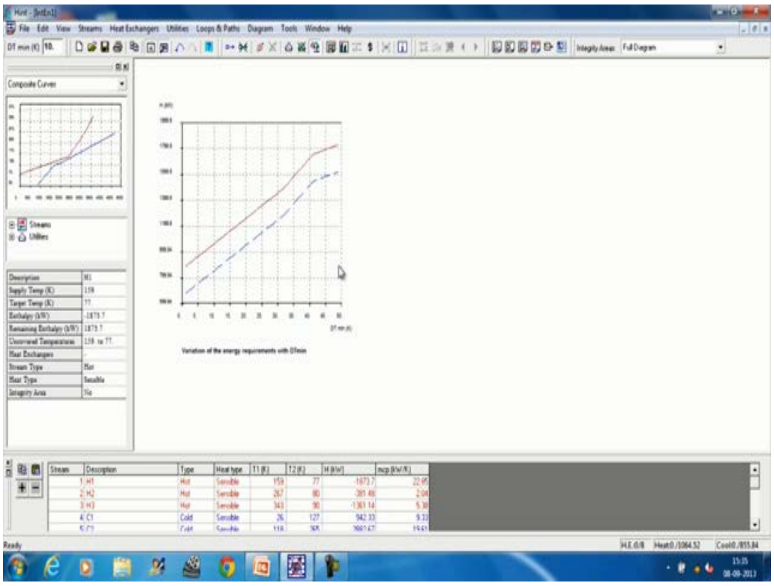

So, if I say high get up lot which shows me the variation of the hot utility as well as cold utility with delta T minimum the other diagram which I can see is area target. In area target also, the minimum value of the temperature deference that is the delta T minimum is 1 maximum is 50 and number of points in raters or 50. Here, it has given the other parameters, so if I say yes, then it shows the area target, that is how area is changing with delta T minimum. So, we see that when the delta T minimum is increasing, the area is decreasing; in this fashion we can go the third point which is pinch temperature.

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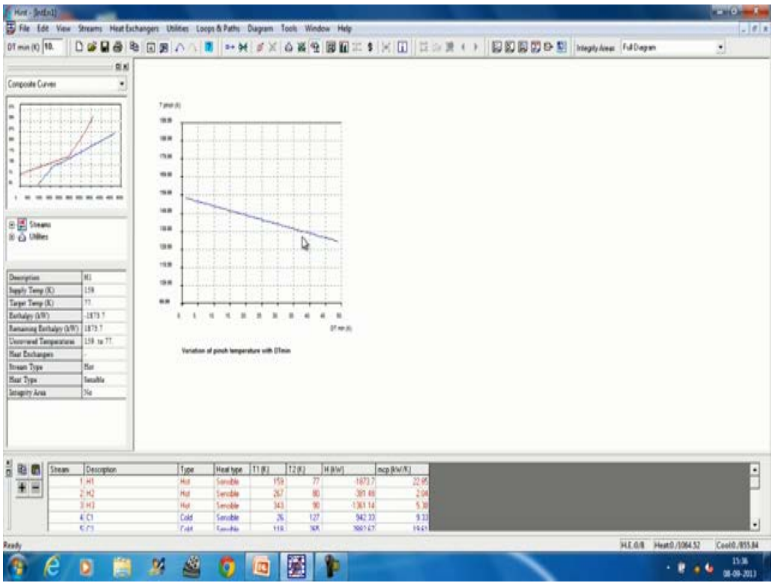

This pinch temperature is also changing with delta T minimum, so basically what we absorbed in this problem that when delta T minimum is increasing the pinch temperature is decreasing. We can go to the minimum number of heat exchange, here we see that the other number of minimum heat exchanges is increasing, this is the very typical phenomena which we have seen.

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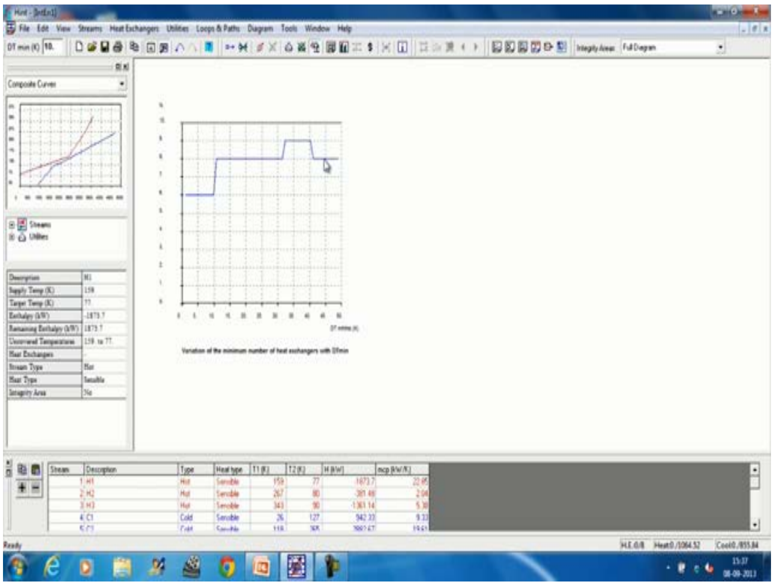

If the delta T minimum is up to 10, we have 6 number of heat exchanges, if it is from 10 to if say around 30 or if a little more than 30, the number of heat exchange of eight, if it is around will little bit more than 30 to 40. The number of heat exchange are 9 and when it is more than 40 to 50, the number of heat exchange of second drop down to 8. So, it is a typical phenomenon which we have a seen which is obviously going to effect the cost of heat exchanges network, we can go for the cost target. In the cost target, we have 3 targets the operating cost, the capital cost and the total cost. If I have the operating cost, say operating cost is increasing rapidly, it is increasing when I increasing the delta T minimum and then little bit rate of increase decreases, and then again rate of increase decreases.

What the overall fashion is that it is increasing with delta T minimum, then I go for the fast target again or my capital that is fix cost here what I see that for heating and cooling the data have be changed. So, again I am changing it to 30,000, this is 400 and this is 0.9, so this is how the fix cost is changing with delta T minimum. This is when the delta T is minimum and is increasing, the fix cost is decreasing and if we go for cost target and total cost this operating cost have change this is 120 this is 10.

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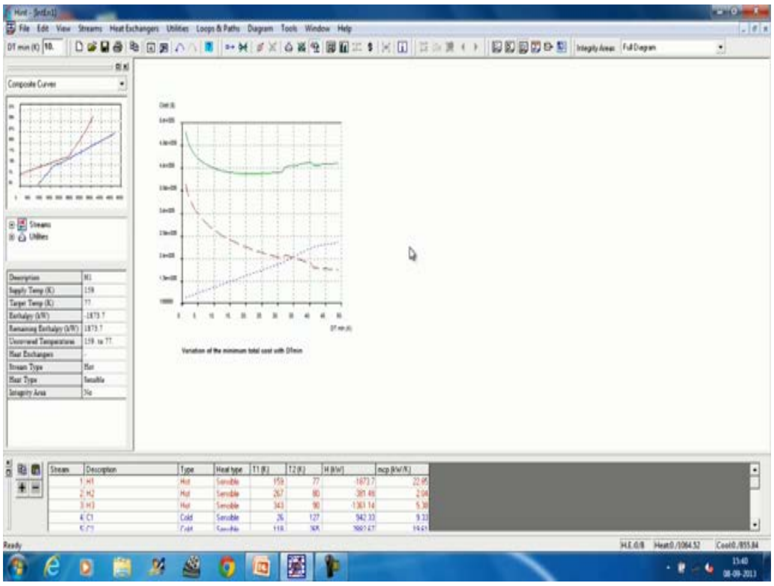

So, we see that this is total cost which is changing with delta T minimum here, we say somewhere here, the minimum total cost heapers which keeps you delta T minimum optimum, but a large flat portion is available here. This means when delta T minimum changes from this point to this point, there is no substantial change in the total cost of the heat exchanger. Then we can go to this more plots and it shows that how the area is changing with heat consumption.

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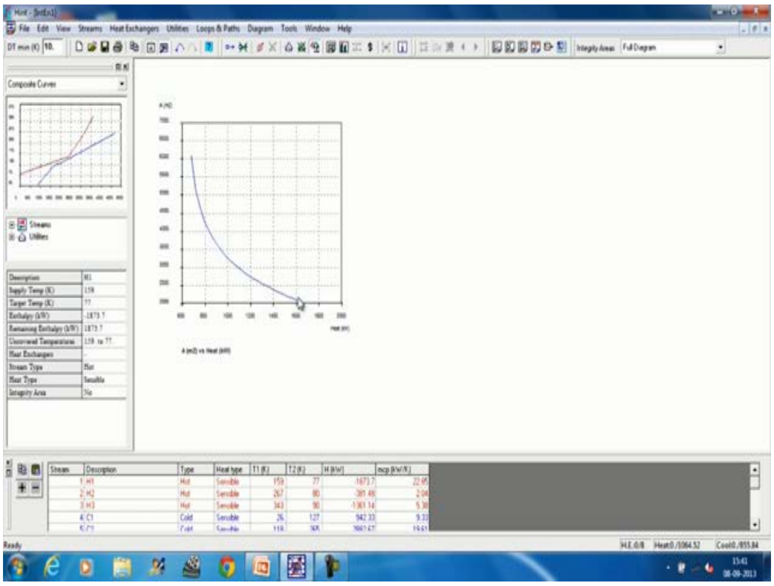

So, we can see this that is shows this when the heat consumption is increasing the area is decreasing. Now, after this we will take up a new problem to show the utility selection when we are feeding this steam data then in the most of the cases unless otherwise specified the program calculates the utility values. Now, if we want different utilities, then we can feed these utilities or if we want multiple utilities that means two hot utilities or two cold utilities we can specify it. Now, the question is that how to specify these utilities and what should be the amount utilities, we will see that if we can specify the temperature of the utilities hint can help you to find out the amount of these utilities.

So, we take another problem, a new problem and try to find out or try to see how the utilities can be specified, we go for a new problem this is H 1, this is 180, target temperature is 75 m C P value is 30. This is H 2 supply temperature is 240, target temperature is 60 and the m C P value is 40. We can go to third C 1, supply temperature is 40 and target temperature is 230. We can go for C 2, the supply temperature is 120 and the target temperature is 300 and the value of C P is 20.

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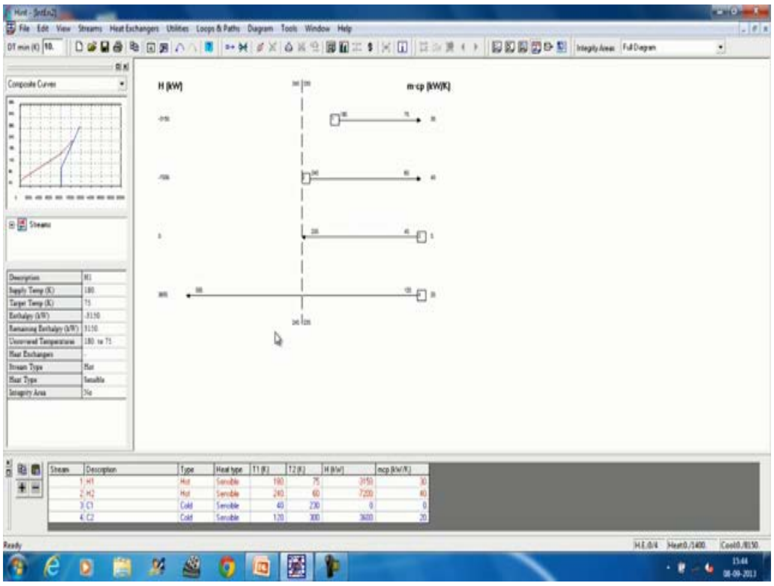

Now, this is our stream diagram and if you see this when we find that our heating duties are 1400 and cooling duties are 8150, pinch temperature is 235 minimum temperature differences is 10 and number of minimum number of units required is 4. Now, suppose how want to specify utilities, so in this may be that we should see the composite curve when we see the grand composite curve.

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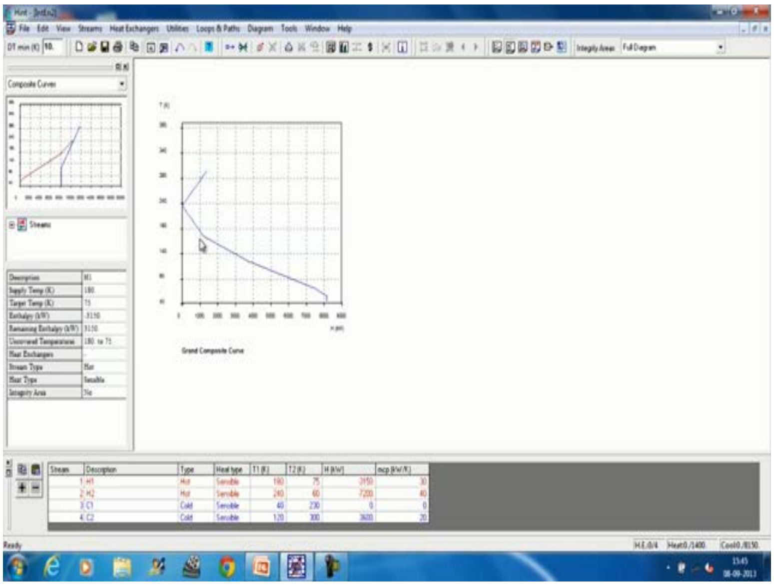

Now, grand composite curve look like this we need a lot of cooling velocity I can provide a hot utility here once single hot utility or I can provide two hot utilities one in this level up to this and then from here to here. So, we will try to put two hot utilities and one cold utilities for this propose, so you go to the utility menu go for add then we here place here plus then we sub change this to 315 and double click here say. So, it automatically turns to be hot utility and then we again press to enter a second hot utility, we enter the temperature to with 255 and double click here 254 and then press ok. Then we enter the third utility, it is cooling utility we guess this temperature 220 and this temperature 230.

Once we finish, this shows you the cold utility here, then we go for combine, now we have already filled the hot utility one temperature ranges that is 315 to 314, hot utility number 255 to 254 and cold utility 20 to 30. Now, we want to see how much hot utility number two is required, so we pull this slider and we see that hot utility number two requirement is 300 units. It shows you here this is the line we show you the hot utility number two and then we pulled it slider of utility number one you see that this line is growing. So, we see that it only goes up to 1,100 and it satisfies at 1,100 and 1,100 plus 300 is 1,400.

So, this is the total amount of hot utility required, so 1100 will be hot utility number one who is from 315 degree centigrade to 314 degree centigrade and hot utility number two numbers two is 255 degree to 254 degree. Its amount will be 300 kilo watt, so it clearly tells that how much are utilities are required at what level become go to the cold utility because cold utility is only one. We see that it is requirement is 80 in 8,000, 150 kilo vat and this is called utility line and this is the hot utility line, so it shows that it satisfied and here we see here a combined with utilities.

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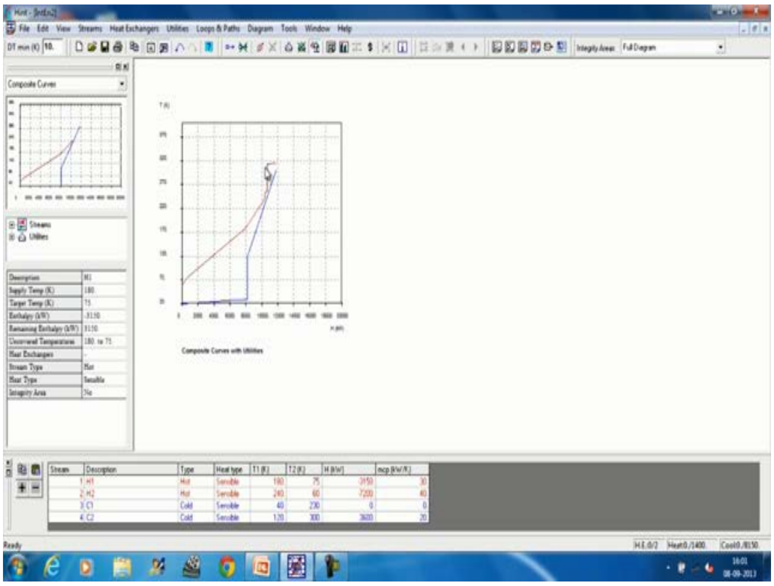

This is compositical, its looks like this is the ordinary compositical composite curve with utilities this is the cold utility from here. This is the hot utility from here to here, hot utility from number two which is 220 degrees to 254 degree Celsius, we see here plus point of two hot utilities and cold utilities. We can go for a grant composite curve and in the grant composite curve, we clearly see the two hot utilities are used it is the first hot utility from here to here which is from 350 degree this is centigrade to 340 degree centigrade.

The second hot utilities from here to here to 155 centigrade to 254 centigrade and the cold utility is from 30 degree centigrade and sorry it is start from 20 degree centigrade it raises to 30 degree centigrade. So, this is the total grant composite curve with utility and if I want, we can see here area targeting and this is this and then we can see other targeting value also. We can see the PTA for this, we show the total utilities demand is 1400 and total cooling duty is 8150 inches, 235 and number of heat exchangers 5 and derivative minimum is 10 degree centigrade. This clearly shows different utilities are to be used in a grant composite curve than how to evaluate among from this utilities using HINT. Now, in the next section we are going to see using the hint software, how a heat exchanger network is designed. First, will go for a MER design, that is maximum energy recover design based on the pinch groups.

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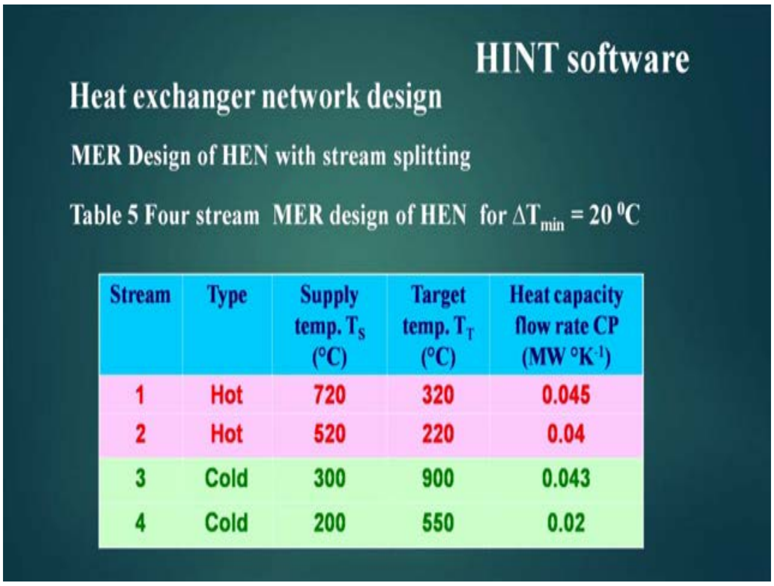

For this, we will take a stream table which is given here with two hot streams hot one going from 720 to 320 or from 250 to 220 and cold from 300 to 900 and cold from 200 to 550. So, this data will take will take here the data minimum to 20 in earlier case we have taken delta T minimum equal to nth degree. So, we start our design and this is a design which I am taking here stream splitting will be required, so we will take two design examples.

In the first design example, we will exhibit how stream splitting is done and in the second example will take a problem where stream splitting is not required. Then with the second problem, we will move forward and will go for a MER as well as non MER the design. So, it start with addition another stream H 1, the supplied temperature is 7, the target temperature is 320 and the m C pvalue is 0.045 mega Watt. So, it will be in the kilo Watt, this will be 45 forty five and then go for H 2, this is from 522 to 20 and the m C p value is 40 in terms of kilo Watt. Three is cold stream C 1, set 300 degree centigrade, goes up to 900 degree centigrade and the value of m C P is 43 in terms of kilo Watt. Then it cost to the fourth number C 2 and the supply temperature is 200 and the target temperature is 150 and m C p is 20 in terms of kilo Watt.

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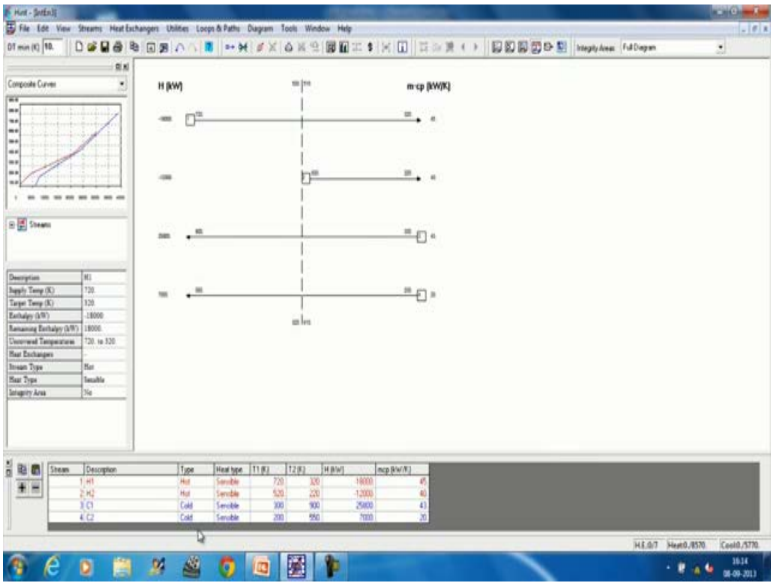

So, stream table is generated here m C P 45, 40, 43 and 20, now this is my stream diagram that is grate diagram and hot pinch is at 520 degree centigrade, cold pinch is at 510 degree centigrade. This means my delta is 10, I have to take delta T is 20, so I make it 20 and executed, now the pinch temperature changes from 520, it is hot pinch is at 520 and cold pinch is 500. So, deference is 20 degree, now this is the grate diagram and now I have the design point.

Now, if I go for stream and try to see the feasibility f of pinch, then what I find that the roles are this is process pinch this is the ever pinch, here I can change below pinch, so I have taken above pinch. Now, my feasibility criterion roles are number of hot streams should be less than number of cold streams and m C p of hot stream should be less then m C p of cold streams. So, here number of cold streams is two and number of hot stream is one, now here we see that in known of the cases the m C p of cold streams are greater than m C p of hot streams.

So, this pose a problem is created I cannot match and hence to do the matching, the hot stream has to be is parted in to two hot streams. So, it satisfies the m C p criteria and matches can be put, so we will try to break this here it is return double click on a stream to split it. So, I double click here, so it tells if this stream is split heat exchangers definitions introduced in this dialogs box will be lost do you want to continue? I say yes, so its gives you another table or spreading.

Now, it says this splits stream number this is one from temperature, so its start from 720 degree centigrade and ends in 520 degree centigrade if branch true two also end seam 510 centigrade. Now, the division is I want one m C pact 40 and the second m C pat 5, so the stream number one is now divided in two streams in the ratio 88.889, 11.1111, now the value of heat that is delta h of this stream is also divided. We see here it is 18,000, so it is divided, let us place this, so I say divide in to two streams and numbers or given as 5 and 640 and 5, it say here as this is put here, so this splits stream is put here.

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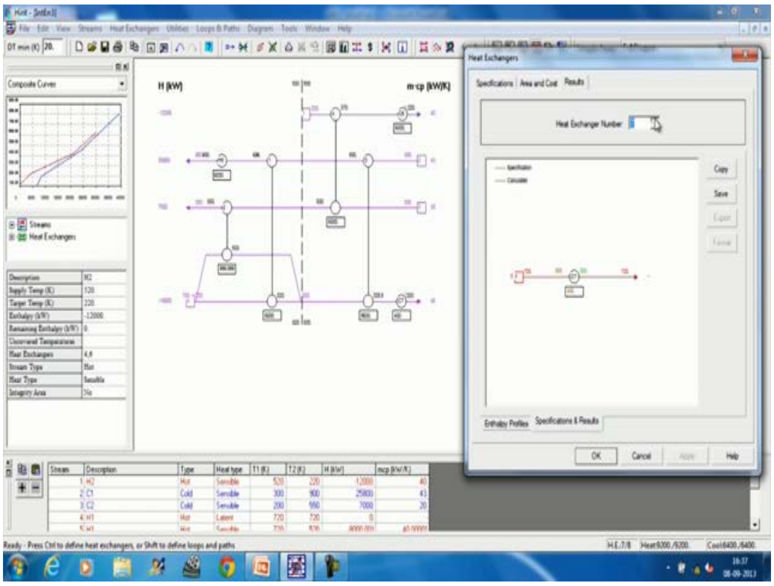

Now, I can take this to this place when and can take this to this place this is the ideal placing of the split streams because above of the pinch this streams split, but not below the pinch, this is 520 degree centigrade. So, this stream this end at 520 degree centigrade and that is I removed moved from this place to this place one this splitting is performed. Now, the placement of heat exchanges would start, now what are you do I will go to the feasibility tells very clearly above of the pinch it has be divided in to 240 and 543 and 23, 20.

Now, this can be done because this satisfies and if I want to see the feasibility feasible matches it very clearly tells the two can be matched with 5 or 6 and 3 can be matched with 6 and below the pinch. One can be matched with 3 and 7 can be matched with other two or three, this possibility keeps it is a feasible match table it gives all the possibilities of matching above the pinch and below the pinch. Out of this, we have to select a few matches, all matches cannot be done and in the remaining problem analysis we see that this matches increase or decrease the area of the heat exchanger network.

So, selection of proper match is necessary and the remaining problem table algorithm helps us to take to select proper matches. Once this is known, we can go to again feasibility and above the pinch because we want to start matches above the pinch and now I want to match between these streams. So, what I can do

I can go for a matching like this say 40, 43, I can match or 40, 43, I can match and 25 I can match so I click this.

I click this, its color changes and then it tells that click on streams to define the heat exchanges, so if click this and they say a heat exchanger will be placed. We saw that a heat exchanger has been placed here. I can shift this heat exchanger any place I like by clicking it, now what it tells that the hot stream entry temperature is 720 to this and exit temperature is 520 and here this heat exchanger starts from 520 and heats up to 686.

Now, I can now go for a second match, I can go to this stream feasibility above pinch and then I can click this and this then I click this and I say a second heat exchanger is now placed. Now, the heat exchanger which is heat exchanger number one transacts 8000 kilo watts and this transacts 999.999 kilo Watt which is approximately equal to 1000 kilo Watt. So, if you add this to this is appears to be 8000 plus 1999 kilo Watts, now I can go to this stream again go to the feasibility below the pinch and I find that there are streams here.

If I see the table here the rules are m C photo should be greater than m C pcold steams and number of part streams should be greater or equal to number of cold streams. This rule is satisfied and m C pof hot streams should be greater than m C pof cold streams; this rule can also be satisfied. So, this 45 can be matched with 43 or 20 and this 40 can only match with the 20, so we see here that will match the 45 with 43. So, if I place this what it tells a m C pof hot which this is 45, 45 and 43. If I said gives a warning, this streams cannot be matched feasibility criterion are not filled, obviously I see that the 40 is not greater than 43. So, it ballets this roll and hence it is not allowing you to do a match, so I will go for 45 and 43.

So, the color changes, that means it will allow me to do the match, so I click this and I say a heat exchanger is crushed and its size is 8600 kilo Watt. Now, I can match a 40 and 20, so I can go so stream feasibility below pinch, so this 40 and 20 can be matched because m C p of hot stream is greater than a m C p of cold stream.

So, I click here, click here the color changes I click here and I say so its place which heat exchanger is four and transacts 6,000 kilo Watt. Now, what are left, all major four heat exchangers has been placed and now we have to place the heaters and coolers. So, for this here I have to put a heater here I have to put a heater because this temperature 550 matches with this temperature. So, this is sticked off these tools and here 686 and 900, that means between this and this heater as do you put up because this is a cold stream.

It needs a heater and the capacity of the heater can be found out by multiplying that is 900 minus 686 into 43, it comes out to be around 9.2 mega Watt that is 9200 kilo Watts. So, I want to place the heater here, so I click this stream and go to the heat exchanger and then a go for add, so it tells me that here that hot stream number five and cold stream number two are being matched. Here, is not my requirement, so I put add here, so it gives me the fifth number heat exchanger because 1, 2, 3, 4 has already been consumed this numbers.

So, my the next number is fifth number heat exchanger so I put add should give me fake number it actually, but here it is given cold utility, it is using and hot stream is this one. This is not the case what I will be using the utilities as hot stream and my cold stream number is 2. So, I will go here and make it to cold stream number 2, sorry I have taken 3 I took cold stream number 2 and here I go for utilities, then I say that I will utilize this enthalpy, my enthalpy I can already calculate this is 9200 and one of the temperatures I have to specify does not required I think any temperatures.

So, it demands a cold stream invade temperature and this cold stream invade temperature is 686, so I can write down 686 and I say yes, so here it puts it puts a heat exchanger which is 9,200. Now, due to the small calculation mistakes which may be after the decimal places sometimes you get something from the software. Some notification from the software, that something is valuating, but you can check it out and you can find out whether it is correct or not, now two cold units that is coolest has to be placed.

Now, if you see this heater this heat exchanger the outlet temperature is 370, the inlet temperature is 520, so 370 to 320, the stream has to be cool down and this will be cool down using a cooler here. Also, we see that the entry point is 320 here, the entry is 520 to this outlet is 328.9. So, you need a to cool this down to 320, so you need a cooler, so let us place a cooler here I click this, I go to the heat exchanger then add heat exchanger. Now, in this I can press add so the heat exchanger number is now 6, my cold utility I will be using and this is between the cold utility and hot stream 1 this is hot stream 1 and I will be using cold utility and the enthalpy required is about 6 mega Watt. So, 6,000 kilowatts and this you can calculate because this temperature is 370, so 370 minus 220, this is 370 minus 220 into 40.

This keeps us the cooling requirement, so I entered 6,000 here, I entered cold stream temperature is not required, so hot stream inlet temperature is I can say hot stream outlet temperature will be 220. So, I say so here I get a cooler 6 was outlet temperature is 220 and the size of the cooler is 6,000 kilowatt. In next, I have to put a cooler here so I click this I go to the heat exchanger say add again I have to go add this this is number 7 heat exchanger. This is between hot stream 1 to utility, this is a wrong information, so my stream is forth, so I will take 4 has my stream and cold utility and enthalpy required this is above 400 kilo Watts and my hot outlet temperature is 320 hot outlet temperature is 320. So, I place a heat exchanger here does not placed here it has placed in a wrong place 320.

Now, it gives a valuation a notice, but if you see that this valuation is not much due to where if calculations we find is very minor valuation. If I make it 400 say 0.12 or so this valuation is removed, but this is a correct heat exchanger network which satisfies the almost all constants. Now, here we have seen that this stream has been split, stream number 4 and this is what we get, now we can go for the heat exchanger network, we can find out the area it gives you the area how were the area will not be correct.

It gives the, takes the default value and then based on that, it calculates the area, but you can correct these values and you can have the correct area and the cost of the heat exchanger network. Now, if you go to the results it almost tells you everything about the heat exchanger network, it gives you the temperature profiles of heat exchangers. You can see all the temperature profiles, how they look like and then you can go for the specifications. It shows you the specification you can change the heat exchanger and all everything you get it here. Then you can go for the area and cost you can go for the results in the results enthalpy profiles specifications results. Here, it shows you the inlet and outlet temperatures, you can change the heat exchanger and you can see this results.

Thank you.