Process Integration
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Module – 4
Targeting
Lecture - 10
Cost Targeting - Part 02

We have already discussed that if the heat exchanges in the heat exchanger networks are made up of same materials, same pressure ratings and same type then the cost targeting becomes easy. However, if the HEN comprises mixed material may be stainless steel, ms, titanium then targeting becomes difficult. In many cases also the pressure rating of the heat exchangers in the heat exchanger network are different and also different heat exchanger types are also used. Say there is a plate heat exchanger, there is a cell and tire tube type of heat exchanger, there is spiral heat exchangers, so if these combinations are there in the heat exchanger network then cost targeting becomes difficult.

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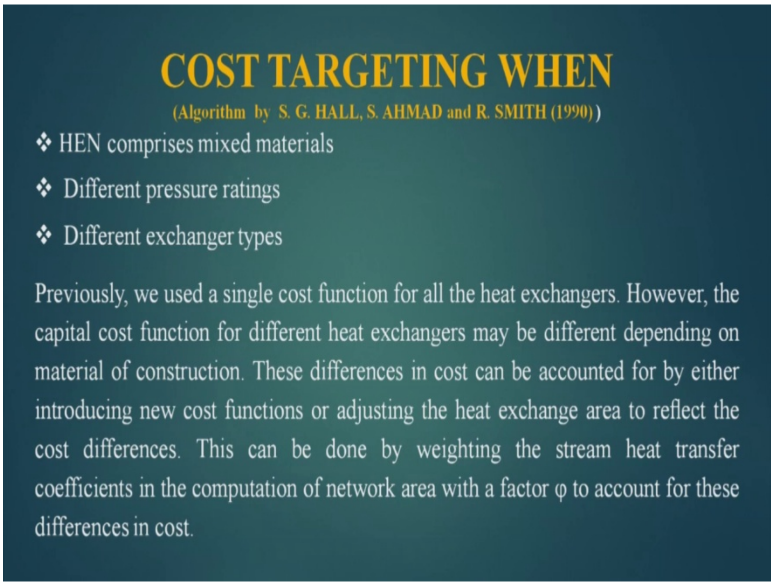

In this scenario, how to do the cost targeting for this algorithm has been provided by S. G. Hall, S. Ahmad and R. Smith. We will discuss that algorithm here to compute the cost of a heat exchanger network, when the specifications of the different heat exchangers present in the network are different. Previously we used a single cost function for all the heat exchangers, and that cost function was a plus b - area of the heat exchanger to the power c. However, the capital cost function for different heat exchanger may be different depending on the material of construction. If the material of construction changes then the value of a, b and c used in the cost functions will be different. This difference in cost can be accounted for by either introducing new cost functions or adjusting the heat exchange area to reflect the cost difference.

The concept is simple that for each heat exchangers in the heat exchanger network either be used different cost functions for computing that area, computing that cost. Or we artificially or virtually increase or decrease the area of the heat exchanger present in the heat exchanger network to accommodate the cost change, which will be there due to the difference in material, difference in pressure or difference in exchanger type. This can be done by weighing the stream heat transfer coefficient in the computation of network area with the factor phi to account for this difference in cost. That means, what we will do to account for this that will multiply weighing factor with the stream heat transfer coefficient, and that factor will be phi to account for all this differences.

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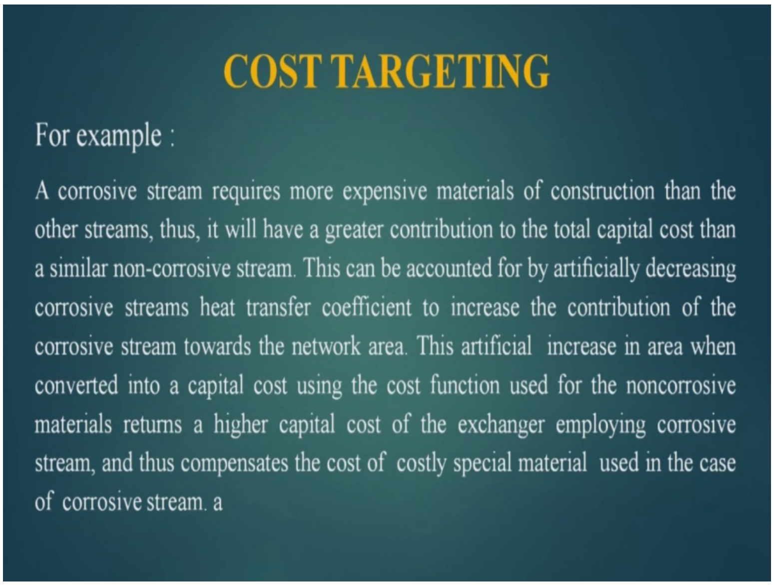

Suppose a corrosive stream requires more expensive material of construction than the other streams, thus it will have a greater contribution to the total capital cost than a similar non-corrosive stream. This is very clear, because to handle a corrosive stream, we have to use expensive material may be titanium in some cases. And if we compared the cost of titanium with the mild steel, which is generally used for ordinary streams then the cost is very very high. This can be accounted for by artificially decreasing the corrosive stream heat transfer coefficient to increase the contribution of the corrosive stream towards the network area. So, if we artificially decrease the heat transfer coefficient of this corrosive stream by a factor phi then it will require more area for this corrosive stream to handle, and thus the heat exchanger cost of this will increase, and hence it will offset the cost. So, if we work on this concept then we can develop a targeting procedure.

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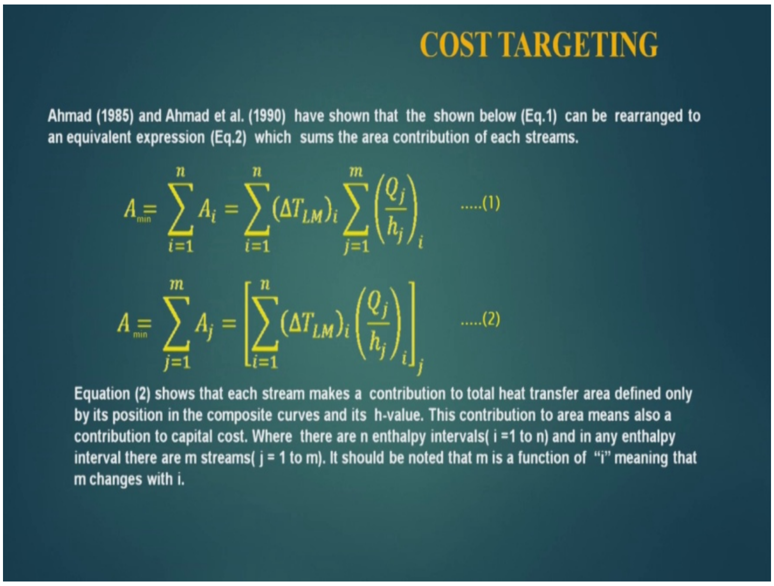

Ahmad in 1985 and Ahmad et al. in 1990 have shown that the equation one can be rearranged to an equivalent expression equation 2, which sums the area contribution of each streams. So, equation one is used to compute the area of a heat exchanger network, this can be modified to equation number two, which have sum up the area contribution of each stream. Equations 2 show that each stream makes a contribution to total heat transfer area defined only by its position in the composite curves and its H value. This contribution to area means also a contribution to capital cost, where there are n enthalpy intervals i is equal 1 to n; and in any enthalpy interval there are m streams where j is equal to 1 to m, it should be noted that m is a function of phi. In this case, basically, what we are doing that what dividing the balance composite cost into i enthalpy intervals, and in a particular intervals there are n streams, which are summation of hot stream as well as cold stream and this m value changes with i.

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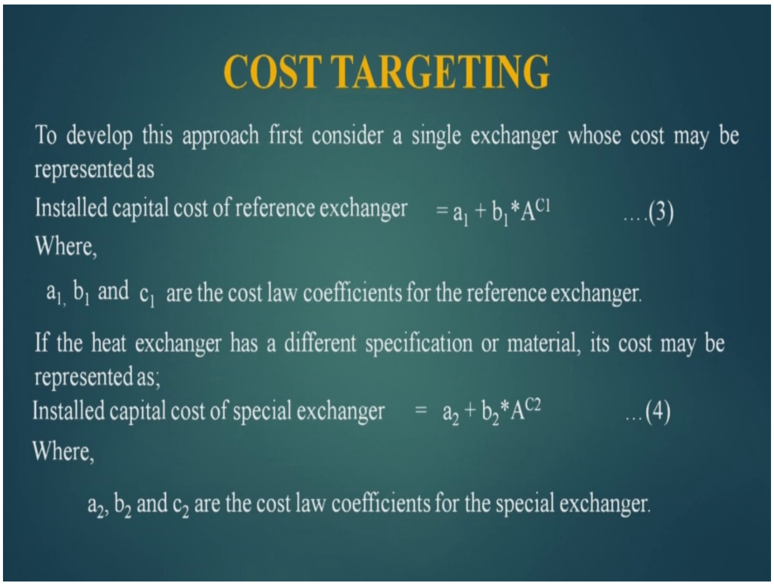

Let to develop this approach fist consider a single exchanger whose cost may be represented as the installed capital cost of reference exchanger is a 1 plus b 1 into a to the power c 1. Suppose reference heat exchanger is made of up of mild steel, we can do the costing with a 1 plus b 1 into A to the power c 1, where a, b, c are the constants which are specially tuned for mild steel. Now if the heat exchanger has in the second case, if the heat exchanger has the different specifications of material, say may be stainless steel its cost relationship will change. May be that cost relationship will be a 2 plus b 2 into A to the power c 2 where a 2, b 2, c 2 are the cost law coefficients of the special heat exchanger.

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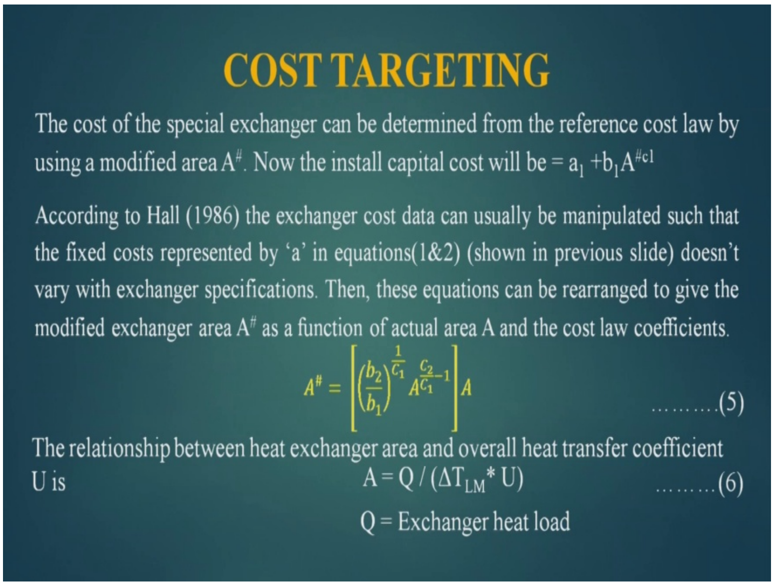

The cost of the special heat exchanger can be determined from the reference cost law by using a modified area A hash. Now the installed capital cost will be a plus b 1 into A hash to the power c 1 what does it mean. Suppose I want to keep the same cost law of the reference material that is a 1 plus b 1 a to the power c 1, yet I want to use this for a different set of materials. So, what I will do, I will artificially increase the area of the heat exchanger or decrease the area of the heat exchanger depending upon the material selected. Say for example, I am using stainless steel its cost is more than the MS, so I have to artificially increase the area of the stainless steel heat exchanger, but I will use the same cost law, which is used for reference material. Now the increased heat transfer area is A hash. then it will be the cost of the stainless steel heat exchanger will be now a 1 plus b 1 A hash to the power c 1.

According to the Hall in 1986, the heat exchanger data can be usually be manipulated such that the fixed cost manipulated by a in equation 1 and 2 does not vary with exchanger specifications. Then these equations can be rearranged to give the modified exchanger area A hash as a function of actual area A and the cost law coefficient as given below - that is A hash is equal to b 2 by b 1 to the power 1 by c 1 then area to the power c 2 by c 1 minus 1 into A. So, it gives me a method to compute the increased area or the decreased area, I will say it modified area of the heat exchanger which has got a different material of construction. And the relationship is with the actual area of the heat exchanger, and here we are using two cost laws - one is for the reference material which is a 1 plus b 1 A to the power c 1; and other is for the different material which is a 2 b 2 A to the power c 2. The relationship between heat exchanger area and the overall heat transfer coefficient U is A is equal to Q divided by delta T L M into U, where Q is the heat exchanger load.

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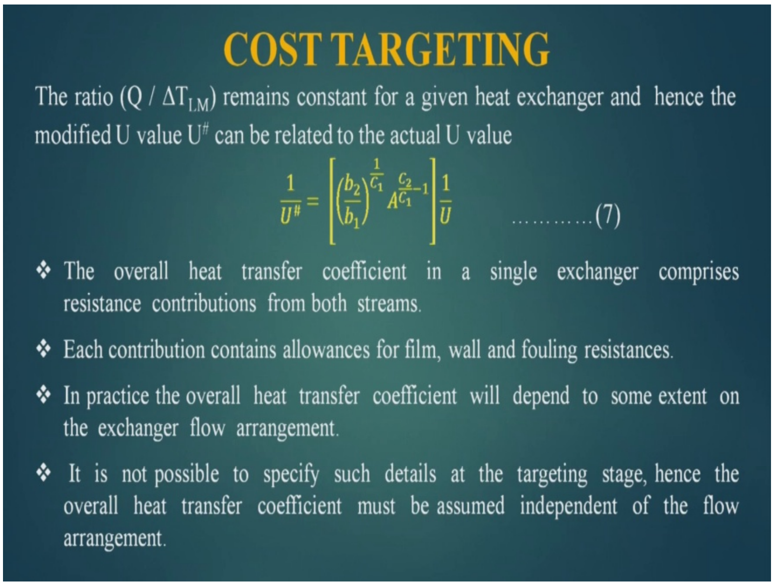

Now these area has to be related with the U, we can find out the relation between U. So, as the ratio of Q by delta T L M remains constant for a given heat exchanger in a particular interval and hence the modified value U hash can be related to the actual U value as given below. So, 1 by U hash is equal to b 2 by b 1 1 by c 1 and A to the power c 1 by c 2 minus 1 into 1 by U. So, now if I use this U hash in the equation U is equal to Q by delta T, I can find out the A hash value. Now this U hash will be broken up into the contribution of each stream that means h hot and h cold.

So, we will see the relationship between the U and the contributing streams. The overall heat transfer coefficient in as single heat exchanger comprises resistance contributions from both streams. Each contribution contains allowances for film, wall and fouling resistances. In practice, the overall heat transfer coefficient will depend to some extent on the exchanger flow arrangement also. It is not possible to specify such details at the targeting stage, hence the overall heat transfer coefficient must be assumed independent of the flow arrangements. It says some lacuna in the targeting procedure, targeting procedures cannot be very very exhaustive and hence we have to compromise in the targeting stage.

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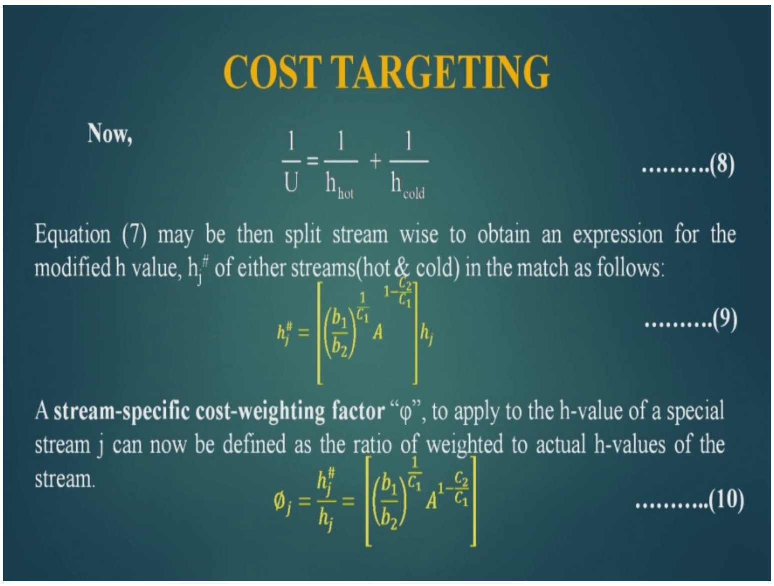

So, now, my aim is to convert or relate this U with the individual heat transfer coefficient of the streams. Now we know that 1 by U equal to 1 by hot plus 1 by h cold 1 by hot heat transfer coefficient of the hot stream plus 1 by heat transfer coefficient of the cold stream. Then equation 7 may be split stream wise to obtain an expression for the modified h j hash; h j means the stream, which is available in the enthalpy and the interval. So, h j of the either stream hot and cold is the match for the as follows. So, based on this we can compute the what will be the value of the h j hash from the U hash and it gives a equation b 1 by b 2 1 by c 1 into A to the power 1 minus c 2 by c 1 into h j. Here we see that earlier it was b 2 by b 1, here it is b 1 by b 1 1 by c 1, and earlier it was A to the power c 2 by c 1 minus 1, it is now A to the power 1 minus c 2 by c 1. So, we are able to find out a relationship between h j hash and h j.

Now the factor phi j, which we have introduced in the first part of the lecture, and this is a factor which will be multiplied to the stream heat transfer coefficient to take into account the specialty of the stream. So, q j is now defined as h j hash divided by h j is equal to b 1 by b 2 to the power 1 by c 1 then into A to the power 1 minus c 2 by c 1. So, now, we are able to find this factor which one multiplied with the actual heat transfer coefficient of the stream will be able to account for the specialty of the stream into account in the equation for calculating the cost. Now this phi is called stream specific cost weighing factor phi, to apply to the h value of a special stream j cannot be defined as given below.

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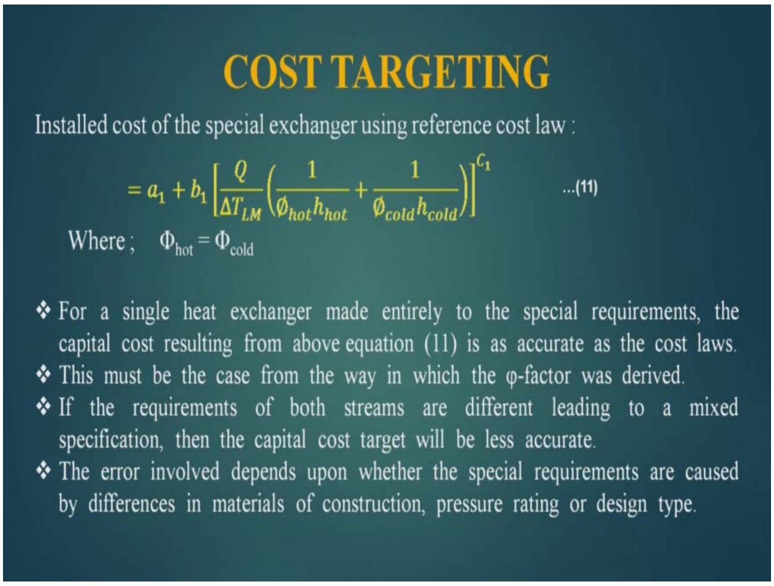

Now once this is known then the installed cost of the special heat exchanger using reference cost law will be this - a 1 plus b 1 Q by delta T L M into in brackets 1 by phi hot into h hot plus 1 by phi cold into h cold. Now here we see that if this stream h of the reference stream as equal to the reference stream hot uses the reference material then obviously, phi hot will be one. And if it is not using the reference material, it use something different material then it is y of phi of hot. Similarly we can talk about this cold stream also. So, this gives you how to compute the cost of a heat exchanger, which requires some specialize material for its operation.

Now if you make phi hot is equal to phi cold, the things becomes more simpler. For a single heat exchanger made entirely to the special requirements, the capital cost resulting from the above equation 11 is as accurate as the cost law itself. This must be the case from the way in which the q phi factor was derived. If the requirements of both streams are different leading to a mixed specification, then the capital cost target will be less accurate. Fourth is the error involved depends upon whether this special requirements are cost by difference in material of construction, pressure rating or design type. We have told you there are three main factors, which makes the cost of the heat exchanger difference that they are material of construction, pressure ratings and design type, because pressure rating will require thicker materials of construction, and hence the cost will increase.

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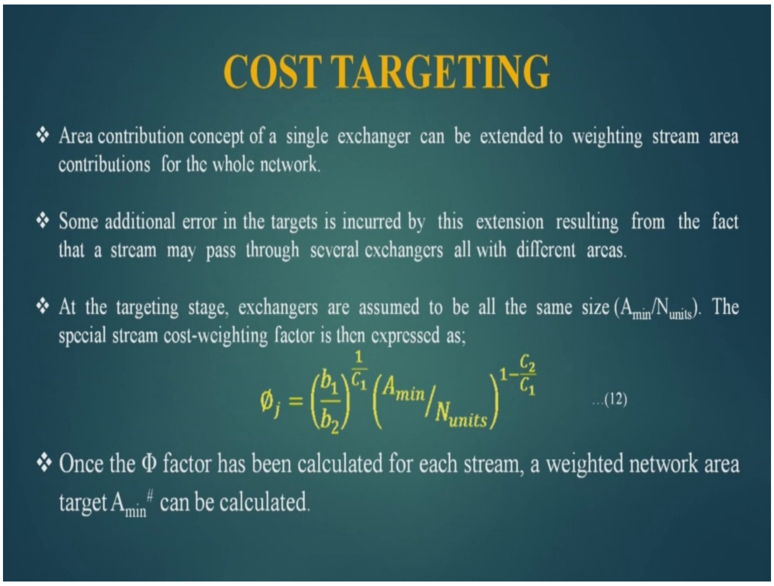

Area contribution concept of a single exchanger can be extended to weighing stream area contribution for the whole network. So, we have to calculate the area contribution concept for a single heat exchangers, now it can be used to find out the exchanger area for the whole network. Some additional error in the target is incurred by this extension resulting from the fact that a stream may pass through several exchangers all with different areas that we have already seen that this is going to increase the error of the prediction of the cost. At the targeting stage, exchangers are assumed to be all the same size. How, because when we are putting up the area and the cost target then we go for the area minimum - that is the area of the heat exchangers network divided by the n units, that is the number of units in the heat exchangers network.

So, this calculate the average area which is not the true in the heat exchanger network, because all the heat exchangers which are present in the network will have somewhat different area. And here we are assuming that they have same area, because the cost equation which we have used are valid for a narrow range of area and it does not cover the whole area range, and if you apply this for a valid area then the then the error is entered into this. This special stream cost weighing factor is then expressed as phi j is equal to b 1 by b 2 1 by c 1 A minimum divided by N units to the power 1 minus c 2 by c 1. Once the factor phi factors has been calculated for each stream a weighing network area target A minimum hash can be computed as this.

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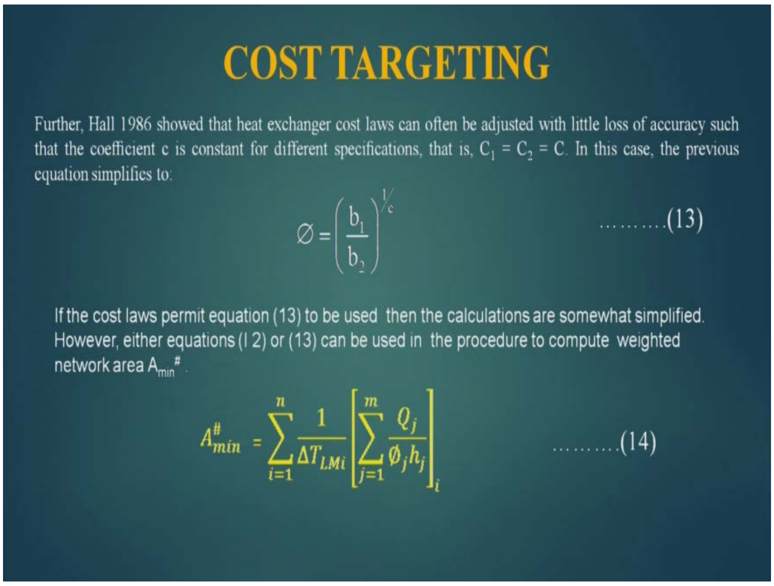

Now further the hall 1986 shows that heat exchanger cost law can often be adjusted with a little loss of accuracy such that coefficient c is constant for different specifications, that is for different materials, that this C 1 is equal to C 2 equal to C. If it is so, then the equation the previous equation simplifies to phi is equal to b 1 by b 2 to the power 1 by c. The cost law permit equation 13 to be used then the calculations are somewhat simplified. However, either equation 12 or equation 13 can be used in the procedure to compute weighted network area A minimum hash. So, once the phi are known, we can put this phi and we can compute the A minimum hash which includes the modified heat exchanger material in the network using the equation 14, where i is the obviously enthalpy intervals and j is for streams which are available in the i, which includes cold streams as well as hot streams.

So, here we see that we have included a stream based factor phi j to account for the different type of specification which are required for different streams. So, using equation 14, we can find out the area requirement of the network of the HENs, which have different they are using different types of materials.

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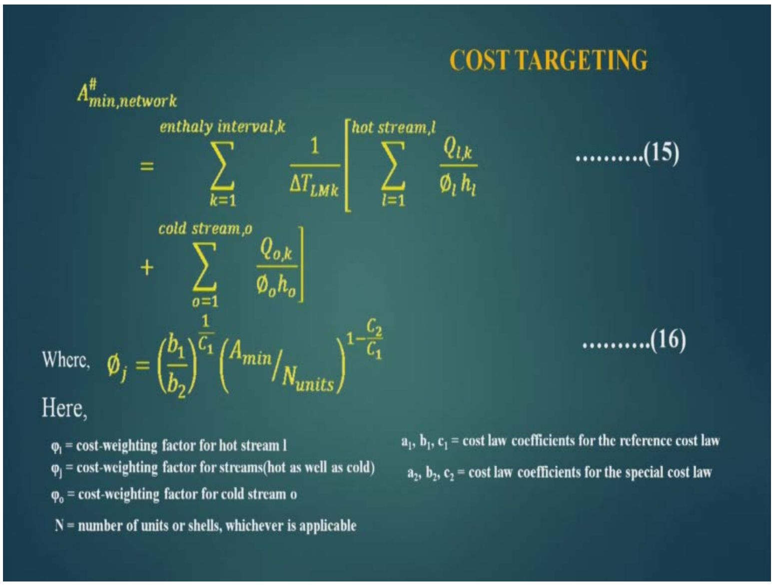

Where the earlier equation, which we have solved there we have taken Q by phi h values for cold as well as hot. Now this can be broken into hot streams and cold streams. So, if you do so, then A minimum hash of the network is equal to summation for the all enthalpy intervals, where k shows you the enthalpy interval, and it is varying from k equal to 1 to number of enthalpy intervals k multiplied by 1 by delta T L M k. That means, for each enthalpy interval there is a constant delta T L M. And when the enthalpy interval is changing, the log min differences temperature is changing then multiplied by in the brackets summation on the basis of hot streams L is equal to 1 to number of hot streams Q l k divided by the phi l h l plus summation of the cold streams which are represented by o; o equal to 1 to number of cold streams, q o k and phi o and h o and the bracket closed.

Where for this purpose phi j which can be calculated by the equation b 1 by b 2 1 by c 1 and then N minimum phi N units to the power 1 minus c 2 by c 1. So, once we compute the Q j for this, where j is hot as well as cold it does not differentiate between hot and cold. So, you can calculate the phi j values for hot and cold and substitute in the above equations, and we can find out A hash minimum network area and this is equation number 15. So, it clearly gives you the nomenclature this is phi L is equal to cost weighing factor for hot stream L; phi j is the cost weighing for the hot as well as cold; phi o is the cost weighing factor for cold stream o. N is equal to number of units or cells whichever is applicable. a 1, b 1, c 1 is the cost law coefficient for reference cost law and a 2, b 2, c 2 is equal to cost law coefficient for the special cost law which is used for this special material.

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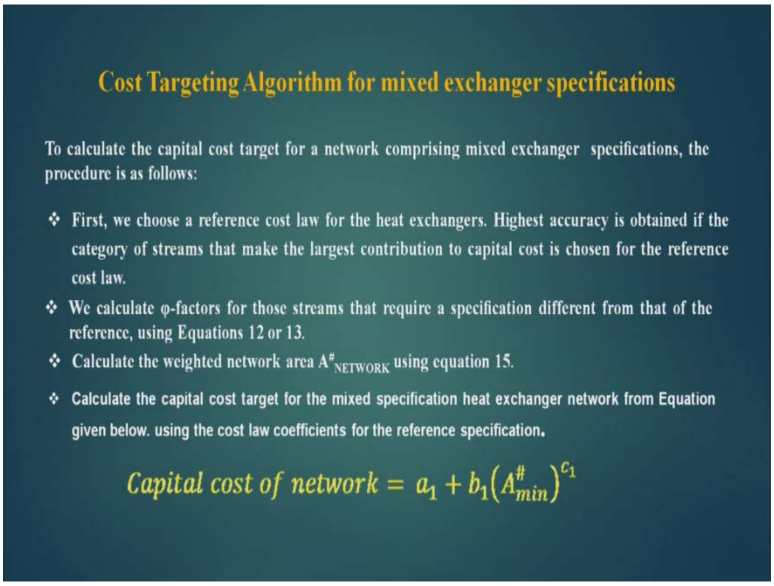

Now cost targeting algorithm for mixed exchanger specifications, let us see this. To calculate the capital cost target for a network comprising mixed exchanger specifications, the procedure is as follows. First, we choose a reference cost law for the heat exchangers. Now how to choose the reference cost law, there are some guidelines for this. Highest accuracy is obtained if the category of streams that make the largest contribution to capital cost is chosen for the reference cost law. Now, basically the category of streams which will largest contribution to capital cost will be near the pinch, because the near the pinch the heat exchangers will have the largest area and once they have largest area they will contribute the more towards the capital cost. So, we have to pick up the streams which have largest contribution and based on those streams we have to choose the reference cost law. So, this will improve the accuracy of our computation.

Second when calculate phi factors for those streams that required a specification different from that of the reference using the equation 12 or 13. Then we have to bring out those streams, which need specialized materials, and for them we will find out what is the phi factor; and for others which are near to the reference material there phi will be obviously one. Calculate the weighted network area A hash network using equation 15. Then the next job is to using the phi factor, calculate the artificially increased network area for difference specification in the heat exchanger which we say A hash network using the equation 5. So, this may area is expected to be more than the actual minimum amount of network area using the area targeting method.

Calculate the capital cost target for the mixed specification heat exchangers network from equation given below. Once that area A hash is known to you us, we can use the cost equation for the reference material, the cost reference cost equation we have taken a 1 plus b 1 A to the power c 1. So, in place of 1 one will put A hash minimum and will compute the capital cost law of the network. Now by doing so, we are in a position to take or consider the mixed heat exchangers specification in the heat exchanger network, and obviously, its cost will be more than the cost of the network, which are based on a minimum that is area targeting.

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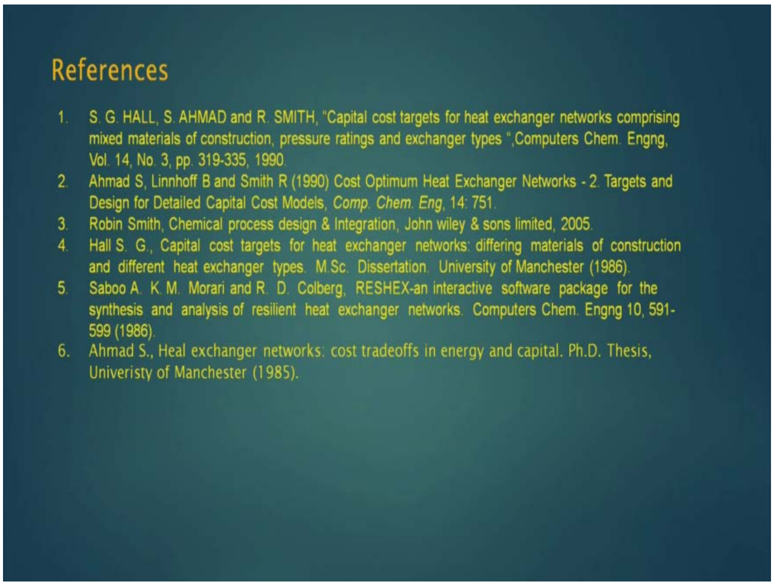

These are the references we have used, and then thank you.