Cooling Technology: Why and How utilized in Food Processing and allied Industries

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Module No 02

Lecture 08
Cooling Load Calculation Contd.

Good afternoon, we are on cooling load calculation right. So, this is the 8th class on total of course. Now this is we are continuing cooling load and perhaps these we have already done, this also in the last class we have done, we have also done this in the previous class ok. Now, we have said that it was all in series right, but there can be different situations some may be in series, some may be parallel or all may be parallel, all may be series. So, it is a different situation depending on how your heat is getting transferred right. This is we teach more in heat transfer, but since it is also coming here.

So, I just said that I will give you some idea so that it does not become Greek to you as you can see here we are in we are in a situation where we have this side is insulated, this side is insulated and it is a one dimensional heat transfer right. If it is one dimensional heat transfer in this side is at a temperature T 1, this side is at a temperature of T 2 right and we have two such media where the areas are different, this is area 1, this is area 2 and the conductivities are also different, this is k 1 and this is k 2. So, what is happening, this Q quantity of heat that, when, is coming here, is getting shared, this is called parallel. So, some part is going through this, some part is going through this right, but again when they are coming out, they are coming as Q because, Q cannot be created cannot be destroyed.

$$q = 2126\ W\ [e]^{0.0484}\ (\Delta T)\ (h)^{1.71}$$

$$Q = \frac{T_a - T_1}{R_a} = \frac{T_1 - T_2}{R_1} = \frac{T_2 - T_3}{R_2} = \frac{T_3 - T_4}{R_3} = \frac{T_4 - T_b}{R_b}$$

where thermal resis tan ces are defined as

$$R_a = \frac{1}{Ah_a} \quad R_1 = \frac{L_1}{Ak_1} \quad R_2 = \frac{L_2}{Ak_2} \quad R_3 = \frac{L_3}{Ak_3} \quad and,\ R_b = \frac{1}{Ah_b}$$

$$\therefore \quad Q = \frac{T_a - T_b}{R}\ W$$

$$where, \quad R = R_a + R_1 + R_2 + R_3 + R_b$$

So, whatever you have given Q, that has to come out, in the steady state, of course. So,this becomes a case of parallel. So, that is what we have given here, Q right and the sameQ is coming out we have temperature driving force, T 1 and T 2 and the resistance 1 is R1, that is L by A 1 k 1 another R 2 that is L by A 2 k 2. So, like the parallel resistances, we have done earlier, in our earlier classes, not this class, earlier academic classes, under graduate, post graduate, wherever it is. So, this we are, we know 1 by R is equal to 1 by R 1 plus 1 by R 2 right.

So, this way we can find out, what is the resultant R right. So, what we need, we need to find out the resistances and those resistances are maybe in parallel or maybe in series or in combination of parallel and series. So, depending on that we are able to find out what is the resultant resistance of the flow of heat Q right. So, this we are able to find out in this case, this was 2 parallel in earlier it was 3 series. So, like that if we look at like that, if we look at this was our, we do not need this, ok.

$$Q = \frac{T_a - T_b}{R}$$

$$where, \quad \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{A_1 k_1}{L} + \frac{A_2 k_2}{L}$$

Q was equivalent to Q T A minus T B R where R is as we said 1 by R is equal to 1 by R 1 plus 1 by R 2 and that is equals to A k 1 by L, since the length was same. If you remember the length was same, 1 second, if you remember, the length was same and yeah, here as you see, the length, it was same for both the cases. Now, we have come that this is equal to A 2 k 2 by L. So, we find out R from here, right once we find out R from here, Q is known or we can find out Q depending on T A minus T B, then the question remain that we said that resultant k, right. The resultant k we can find out from here that is your Q is known delta T is known you have found out L, R.

So, from that R you are able to find out the resultant equivalent k right. So, once you find out equivalent k then you are able to find out what is the load, cooling load for that insulation or the container or the room right. Then we move to, this is another case, this is another case, that is as we said in combination, in combination means you have you have this one the Q is coming through this, then it is divided into 3, one this, one this, and one this, then again going it to one only this, finally, going out to T 2. So, driving force is T 1 and T 2 and of course, the other sides are insulated. This is only one dimensional right.

So, this is only one dimensional, others are getting insulated ok. Like this we can find out that what is the Q and then we find out the equivalent conductivity. So, in this we have then shown really you, either all series or all parallel or a combination of series and parallel. All 3 cases we have shown you, which are probable and you can find out the resistance from where you can find out the equivalent conductivity. Now, once we know that our next performance is, let me also clear it up.

Next performance is that heat in leak through cracks and crevices right heat in leak through cracks and crevices. So, what is that? As I said earlier that every building may have, it is not necessarily it will always have, may have some cracks or crevices and through them like cracks and crevices, if we draw, you will see that, say this is the wall, right wall thickness, there may be a slight crack like this. Now, if you have this kind of crack what will happen? This outside is 34 degree or say 40 degree and this inside is say minus 10 degree say. So, your delta T is so high as 50 degree. So, what will happen? The air from outside that will get into it through the crack very easily.

So, you are making a thoroughfare if you are having a crack in the building or in the container, where you are doing it right. So, that you have to be very careful while calculating whether any such unit is there or not. If it is, you have to take care. So, the majority of the heat is transferred due to the fluctuations in pressure caused by the fluctuation in temperature in the enclosure. At the high temperature point in the temperature cycle, cold air will be expelled out from the room and at the low temperature rather point where the pressure drops warm air will be drawn from outside into the room.

This is what if you have cracks and crevices. Now heat leak through the doors, open doors. This is another typical one. I gave you the example of household refrigerator, this is what exactly one household refrigerator. I am showing you.

You see, the door is so much, right the door is so much, and if you open the door, the entire bulk air gets into the freeze. Outside may not be as high as outside of your building, but still in the summer it is around 35. So, the 35 and inside is around 4 degree. So, that 35 air is refreshing inside 4 degree. So, the compressor has to work again very high.

So that, this fresh air is cooled to 4 degree. So, it is an additional load for the compressor, that is why you should tell your seniors or parents or who are handling the refrigerator, that please do not keep the door open, whatever you need to take, you take it out, close the door and whatever you do that take the entire or part of it and put it back, open the door and put it and again close the door. Keep the door closed as much as possible that will minimize the heat load. So, this is true everywhere in the small scale with this we are showing right in the larger scale the doors are even much bigger in the cold rooms, the doors are very very big because lot many people get into it with the product for keeping as well as for taking out. So, there, the doors are supposed to be big.

So, lot of fresh air getting in when we will come to cold store you will see that such big big doors are there and big big buildings are also there and you are doing what? Unnecessarily keeping the door open, allowing fresh hot air to get in and get it absolutely warm up which is not required. So, opening doors each time allow entry of warm air and exit of cold air. The rate at which heat is incurred that depends primarily on the following aspects number 1 size of the door, number 2 temperature differential between the inside and outside right. As I said 35, if it is, no, maybe in winter it is 25. So, delta T is less there delta T was more, size of the door normal household doors are 7 feet wide and large, but cold room doors are much more than that, maybe around 10 12 around 10 feet and the width is also maybe 8 to 10 feet.

So, that is a huge one because the people, they will take on their head this bags full of the produce and either store or take out the bags with their, I mean on their head, that is how in India, as of now is, because, very very rarely things are automatic very rarely. So, if it is automatic then lot of problems are solved, because you do not have to keep the door open, you can put it or dump it with automatically and unload it also automatically some conveyor belt will be there. So, they will convey and there will be people who will be taking out and put it in the right place right. So, door size and the temperature differential, these two are absolutely fundamental for the heat leak through the doors right. For example, we can do a problem.

So, this is an empirical relation to determine the rate of heat transfer through doors of refrigerated rooms that is between 22.2 and 66.7 degree centigrade and the relation is Q is equal to 2126 W e to the power 0.0484 into delta T into h to the power 1.71. I repeat that Q quantity of heat, this Q is rate of heat in leak that is in watt joules per second right because any rate means per unit time whatever it be any rate is per unit time that is how velocity is also meter per second. So, like that so, Q is the rate of heat transfer in leak in watt 2126 is a constant W is the width of the door in meter delta T is the temperature difference in degree centigrade between inside and outside the room and h is the height of the door right. The moment you are seeing 2 that means, you know the area and area means it is the, that Q is equal to U A delta T, that A is known right. So, by this we can find out if this is a correlation between the heat transfer rate in the doors where the size of the doors and the temperature difference between them is between 22 to 66 degree centigrade right. So, likewise this is a semi empirical relation right maybe some empirical relations or experimental relations also can be developed.

In this, I refer to you one very very important book that is called ASHRAE right. This ASHRAE handbook if you look at all this you will get it all this you will get it because this is perhaps American society for heating and refrigeration and air conditioning engineering or something like that whatever it be you get lot of relations lot of information in that. So, that is very very useful. So, what we now can do is that solving a problem and showing that how much really heat is getting into when the doors are getting opened. For example, a 3 meter high and 2 meter width refrigerated room is opened and closed 10 times in every hour and each time it remains open for 1 minute.

The refrigerated load in a day due to the door opening, if the room and the ambient temperature is maintained at 0 degree centigrade and 30 degree centigrade respectively, in mega joules right. And you have to find out which one is correct A 2000 mega joules B 1801 mega joules C 1711 mega joules or D 2052 mega joules right. So, this you can do of course, I have done it for you, but you can also do to understand. Let me tell the problem again that a 3 meter high and 2 meter width, you see, 3 meter high. That means, it is almost 10 feet and or beyond 10 feet and 2 meter width means almost 6 7 feet.

So, it is a wide refrigerated room, is opened and closed 10 times in every hour and each time it remains open for 1 minute. The refrigeration load in a day due to the door opening, if the room and the ambient temperature is maintained at 0 degree centigrade and 30 degree centigrade respectively, and you find out in terms of mega joule and tell which one is correct whether A, 2000 mega joules, B, 1801 mega joules, C, 1711 mega joules, or D, 2052 mega joules right. Now, our given things are 3 meter and 2 meter right. So, h is 3 meter and w is 2 meter. Also you are given delta T of 30 minus 0 that is 30 degree centigrade.

Therefore, from the previous relation, if you remember the heat in leak rate can be found out from the relation q is equal to 2126 into, it was having 2126, if we go back here, it was 2126 into w, w is the width of the door into e to the power 0.0484 into delta T into h to the power 1.71 h, h is the height, w is the width and h is the height. So, here we are writing that q is 2126 into 2 that was width, here it is 2 meter.

So, 2 into e to the power 0.0484 into delta T that is 30, into h to the power 1.71, h is 3. So, 3 to the power 1.71 and if we calculate it it comes 1188.7 kilowatt, but we are asked to find out what is the heat in leak if 10 times an hour, it is opened.

So, the door was opened for a total time of 240 minute, because 24 hour a day. So, 24 into 10 is 240 minute, the door was opened in a day and this means it is 1.44 into 104 seconds right. So, the refrigeration load we can find out that kilowatt right, times the second is mega joule and that is coming 1711 that is c) is the correct answer right. So, this way if we do some more problems, we can come to know what is the real heat load due to the door opening, coming and it is a huge quantity as you see that 1711 mega joules right.

Given, $h = 3m$, $W = 2m$, $\Delta T = 30\ ^oC$,

$q = 2126\ [2]\ [e]^{0.0484}\ (30)\ [3]^{1.71}$

$= 1188.7$ kW

The door was opened for a total time of 240 min

= 1.44 X 104 secs.

Refrigeration load in a day = 1711 MJ

So, it is a huge quantity is equal to 1711 into 10 to the power 3 kilo joules right or 1711 into 10 to the power 6 joules. So, much of heat load which is coming ok. So, next day we will do some other, maybe some calculations, are not over because it is so big and so fundamental that unless you know it, you are not able to find out, ok. Thank you.