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

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Module No 02

Lecture 09

Cooling Load Calculation Contd.

Good evening. We are still doing some calculations, some more knowledge on heat load or cooling load, right or in terms of refrigeration load that we are doing and previous class we have talked about what is the effect of door opening right. Now, let us come to another very important and that is called heat generation right. So, there are many ways by which heat can be generated, many ways. For example, here we have given, some sources of heat generations are like motors. Motors may be inside the room or outside the room, depending on situation, if it is inside the room one type of heat transfer, if it is outside the room another type of heat transfer that is what we have given some numerical values, so that you understand the differences and you know some values, which are associated. Now motors are, may be inside the room for different reasons, for running something for many other reasons. So, if motors are inside a refrigerated room heat is generated at the rate of 1025.5 watt per hp again depending on the motor size.

Generally, our all household needs, we have seen, the motors are generally 0.25, 0.5 hp or 1 hp at the most, but in commercial level it may be several hps, right. So, it is 1025.5 watt per hp and if the motors are outside the refrigerated room, but the load it drives is outside, then the rate of heat generation is 732.

5 watt per hp right. So, if the motors are inside, one type of heat generation, if the motors are outside, another type of heat generation, and the difference is substantial, right one is 1025.5 per hp another is 732.5 watt per hp. Now this is one way of generation of heat.

There can be other ways, like, people, I told many times that people go inside with the bags full of the commodity which is to be stored or taken out. So, they also incorporate lot of heat. For example, if workers are there, they generally generate around 293 watt per person inside a refrigerated room. So, 293 watt per person this is a unique number. So, somewhere 300 watts per person is generated and generally in any big cold room there are, I mean, tens of people who are working inside, some or other kind of work is doing.

So, a constant heat source of say 293 into 1015 so much wattage is unavailable because of the persons who are working. Another, as I told also earlier, light. So, it dissipate heat that is equal to the wattage of the lamp. Generally, we know the lamp wattage, 60, 100, 200 wattage of the lamp that depends on that how the cold room is built up right. However, this gives an idea about the light, which is inside the cold room.

Then as we said earlier, respiration, generation of heat, light, from the light, from the people, from the motors, are the generation. Respiration is also another kind of generation So, if the commodity stored is fruits and vegetables, then it respires heat of respiration adds to the refrigeration load. Generally, this heat of respiration is a function of temperature and can be calculated as this is also an empirical relation as Q equal to A into e to the power B T, $q = a\,(e)^{bT}$; B into T, where Q is the rate of heat generation in milli watt per kg, A and B are the constants that varies for different fruits and vegetables or different commodities. T is of course, the temperature at which heat of respiration is calculated, right. So, heat of respiration decreases as temperature of the refrigerated room decreases.

This also I told you earlier, given the example of people, who are in the high altitude, their respiration rates are less than people who are in the sea level, right. Because at high altitude, temperature is low so, the heat of refrigeration or heat of respiration is also low. Whereas, people who are on the bank of the river or on the sea level their heat of respiration is much higher, right. So, we can, this is a very very empirical relation, where A and B are constant and this constants are dependent on the commodities which are being used, right. So, let us look into an average heat of respiration is calculated between two extreme temperatures of the room say T 1 and T 2.

$$q = \frac{1}{\Delta t} \int_0^{\Delta t} a\,(e)^{bT}\ \Delta t$$

$$T - T_1 = \frac{T_1 - T_2}{\Delta t}\, t$$

$$\therefore q = \frac{a\,(e)^{bT_1}}{b\,(T_1 - T_2)}\left[1 - (e)^{-b(T_1 - T_2)}\right]$$

I believe you also know it very well that if you are in your house and if the house or door or rather room is a little big say 20 by 20 feet, then, you may have conditioners or cooling or fans, and it is not that the fans are at every point, maybe at two locations, or three locations, fans are there. By chance, if you have a digital temperature indicator, of course, it will have one thermocouple, or sensor. So, if you roam around the room you will see that the room temperature is not same though the fans are running or if there is conditioner, air conditioner also, or cooling also, then also it is not that every point, the temperatures are uniformly same, right. So, this is obvious, and we are saying that if those conditions, two extreme conditions are T 1 and T 2 then the average of them can be said that the heat of respiration is average of those two T 1 and T 2 right. And if the time required for the two temperatures are T 1 and T 2 as delta T and if the change of the temperature is linear, if it is non-linear then it is very very difficult, not difficult it becomes more mathematical oriented.

If it is linear then you can do it very easily so, if the changes are linear and the time required for the temperature to drop from T 1 to T 2. If T 1 is higher and T 2 is lower and then, how you want to find out the average temperature, rate of respiration. Then there is a correlation between the heat transfer rate and the delta T as well as the coefficients constants right. So, we can say that the average rate of heat of respiration over a time period of delta T small t this can be calculated from the relation as q is equal to 1 by delta 0 to delta T A into e to the power B into T into delta T. I repeat the average heat of respiration that can be said as q is equals to 1 by delta T in 0 to delta T into A into e to the power B capital T into delta T time this a again empirical relation right.

So if the temperature change is linear then we can surely write that T minus T 1 is equals to T 1 minus T 2 over delta T into T right. So, T minus T 1 by T small t is equals to capital T 1 minus capital T 2 by delta T of course, capital T's are temperatures and small t's are time right. Then we can write that relation again in a better way as q equal to A into e to the power B T 1 over B into T 1 minus T 2, T 1, if it is higher times 1 minus e to the power minus B T 1 minus T 2 right. I repeat that the rate of heat of respiration can be found out as A into e to the power B T 1 over B into capital T 1 minus capital T 2 into 1 minus e to the power B into T 1 minus T 2 where T 1 and T 2 are the temperatures right. This is a or this is an empirical relation.

So, we can find out how the heat of respiration amounts by doing some problem so that the quantum of heat generation this we can find out easily. For example, apples are cooled from 35 degree centigrade to 2 degree centigrade in 5 hour time. Calculate the heat of respiration during this cooling period. The coefficients of heat of respiration of apple are A equal to 19.4 milliwatt per kg and B equal to 0.

$$q = \frac{19.4 \quad e^{0.108\ (35)}}{0.108 \ (35 - 2)}\left[1 - (e)^{-0.108\ (35 - 2)}\right]$$

$$= 231.7 \text{ mW / kg}$$

108 degree centigrade inverse. Inverse of degree centigrade that is the unit of B and unit of A is milliwatt per kg of the material. So in this case we are talking about apple had it been say guava or say mango then these values of A and B would have been different. So the rate of heat respiration we can find out from this problem as like this. Apples are cooled from 35 degree centigrade to 2 degree centigrade in 5 hour time.

Calculate the heat of respiration during this cooling period. The coefficients for heat of respiration for apple are A equal to 19.4 milliwatt per kg and B equal to 0.108 degree in centigrade inverse right. Obviously, we know that relation just in the previous one, I go back to that, this, we had shown empirical relation Q is equal to A into e to the power B T 1 over B into T 1 minus T 2 times 1 minus e to the power minus B into T 1 minus T 2.

If we use this then we substitute the values then it becomes Q is equal to 19.4 over 0.108 into e to the power 0.108 into delta T that is 35 over 0.108, that is the value of B into T 1 minus T 2, is 35 minus 2 that is 33 into 1 minus e to the power minus 1.

08 into 35 minus 2. So, if we solve it here, the values are like that T 1 is 35, T 2 is 2 degree and A is 19.4 whereas B is 0.108. So, only these four are used and we get the value of heat of respiration of apples between 35 to 2 degree centigrade as 231.

7 milliwatt per kg, 231.7 milliwatt per kg mind it, right. So, 231.7 kilo milliwatt per kg that means, if you have 100000 kg. So, 100000 into 231.7 milliwatt, yes for milli 100000 goes out.

So, it becomes 231 into 100 that means, 23170, so much of watt per 100000 kg, right. So, this gives us an idea. Next another problem if you look at the coefficients for heat of respiration of head latches are 26.7 milliwatt per kg and 0.

088 degree centigrade inverse. What is the refrigeration load if head latches is kept at a constant temperature of 3 degree centigrade? I repeat the coefficients for heat of respiration of head lettuce are 26.7 milliwatt per kg and 0.088 per degree centigrade. What is the refrigeration load if head latches is kept at a constant temperature of 3 degree centigrade? Now, we have seen, in the beginning, it was a relation that Q is equal to A into e to the power B into t that was one such relation if you remember. So, if you substitute those values of A and B and temperature T, then we get 26.

7 into e to the power 0.088 into 3 is equal to 34.7, so much below milliwatt per kg right. So, this is for head latches, both are of course, good respiring and this we have seen that the heat of respiration is around 34.7 milliwatt per kg right. So, what we then come to the conclusion that the heat of respiration is also one of the major heat load and heat of respiration is also seen as a function of temperature as well there are some correlations available and these correlations are function of the material.

If the material is known and its constant values are known and if the temperature from where to where it is getting changed is known then I, it is seen that we can predict the respiration rate from the given empirical relations and once the empirical relations are used perhaps we get the heat of respiration very very accurately and that gives us one type of heat load and other loads which we also discussed are the load. There is also one more load which we have not said is the fan. In most of the cold rooms to have the temperature difference as little as possible, but to have the convective coefficient convective heat transfer lot many fans are used and each fan has an wattage that is also known. So, if the wattage of the fans are known and wattage of the lights which we have also said is known then we can find out what is the load from the product itself. Number 1 respiration, number 2 the handling of it and the other loads such as load due to our motors which are used for many cases, then human beings, which are going in and out for number of times and doors, which are opened and closed very irregularly or in most of the cases during the loading of the cold room.

In most of the cases, it is seen that the door remains open. And in that case, we have also shown that size of the door is a definitely function of the heat load because size of the door, if it is a household refrigerator size of the door and actually it may be several times, several times the area of the household refrigerator then of course, the load of the heat will be quite different. So, if you have questions you may ask and of course, you will have some platform from where you can raise your questions and supporting people will be answering to them right. So, at least new things which you have come across is the respiration heat, is the heat due to motors, right these and the heat load per person, who is entering and coming out each time, how much quantity that you have already found out, right. So, I hope you are able to get it and next after the respiration load we may be going into the basics of thermodynamics.

So, unless we know the basics of thermodynamics where all the laws are also recapitulated and also all the laws in the meaning that thermochemistry or chemistry oriented reactions or relations they are also to be looked into and, but mostly it is thermal right mostly it is thermal because we are handling with thermal only because heating being a thermal cooling is also a thermal. So, we should know that how heating and cooling both are getting into the heat load right. So, with this I think we can complete that cooling load calculations once we have the cooling load someday we will also come that how much tonnage of refrigeration is one ton of refrigeration is what is the kilowattage of that right roughly it is 3.5. So, once we know the cooling load or heating cooling load in this case then we know the tonnage of refrigeration required because one ton of refrigeration is roughly 3.

5 other decimals are also there 3.5 kilowatt right. So, with this we complete this cooling load calculation class. Thank you.