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

Prof. Tridib Kumar Goswami
Department of Agriculture Engineering
Indian Institute of Technology, Kharagpur

Module No 02

Lecture 06

Cooling Load Calculation

Good afternoon. Hopefully, you remember that in the previous week, we have completed why we need cooling. What is the need of cooling? Why you should, other than cooling, whether it can be done or not? This, we have discussed in detail right. Now, the question comes if cooling is required, then how much, that is a first question, how much cooling is required? Like in this room, where I am giving this lecture, there is a cooling. This cooling is not for human or the comfort of the teachers, who are taking classes. This cooling is primarily for the instruments and equipment, which are used for this lecture, but it is also a cooling load, right.

Like, you cannot see that, this is a 4 wall so and obviously, it is also soundproof, but to make it, and of course, there is door, the other day we have also shown you door, today also we will show. So, all these are factors that how much cooling is required. The other day, I told you or if by chance I have missed it, then let me also tell, if you remember, and if we, if you are acquainted with the present day activities, then you might have seen couple of months or year back government of India requested all the manufacturers of household air conditioners, and also commercial air conditioners, to operate not below 24 degree centigrade. Generally, you will see any air conditioner if you put on, as on today, that it can go up to 18 or 16 degree centigrade, that is too cold.

In our country 18 or 16 degree centigrade is too cold. In developed countries, in many places, they may have this 18, 16 degree normal because it goes down to 0 or sub 0, at this very moment, my son is at Philadelphia. So, I come to know that their normal temperature has now come down to 8 or 7 and which is within a, perhaps couple of weeks, it will go to sub 0, to minus 15, 20 or even lower. So, for them this 16, 18 is not a problem, but for us definitely 16 or 18, is too cold, and as you lower down your temperature, desired expected temperature, the more will be the cooling down, means more compressor has to run, not only compressor, compressor, condenser everybody. So, more energy is required, the moment more energy is required, that will be, that will have to be provided by the provider rather in this case, we can say the government of

India or the state government who so ever.

So, that is why, perhaps there was a circular that please keep your air conditioners not more than or rather not less than 24 degree centigrade because, between 24 to 26 this is one of the comfortable zone. This is more or less comfortable zone throughout India. So, that was perhaps, it did not come just like that, there are many experts to look into this and then only any government, they decide on whatever process or procedure to be followed. So, we need to know the cooling load. So, today's class, that is why we are dedicating to the cooling load, right.

So, if it is cooling load, then as you can see that refrigeration or cooling load calculation. In this slide and we are saying obviously, cooling load means how much refrigeration you have to provide, in other word that is the cooling load. So, refrigeration load, as we have seen that, it is divided into two parts one is unsteady state load and another is steady state load. The moment I say unsteady state load and steady state load, you will say we have not understood what you said? Then let me explain that steady load is, which is time independent, anything steady in terms of engineering or science is time independent and anything unsteady is time dependent, right. So, with time, it may change, but the steady load does not change.

In that steady load, we can divide them into, like sensible heat, heat of respiration, if it is a fresh produce, heat of fusion of water in the product, heat of fusion or heat of, sorry, solidification whatever you call, they constitute the part of the load. I should not say it is fully steady or fully unsteady, this is the part of load, right, because as you see sensible heat means your room temperature was say 40 degree centigrade and you want to bring down to 24 degree or 20 degree centigrade. So, there is no phase change, right. So, this lowering of temperature from 40 to 24 degree centigrade or 20 degree centigrade is the sensible heat because there is no phase change, as we are respiring we are living, means respiring, anything living means respiring. So, the produce, which you will be keeping, if it is also respiring, then it will have a load and I will come afterwards in respiration and it is also a unsteady.

Then heat of fusion of water in the product, if it is, we are not talking about air condition only, we are talking about the refrigeration load right. So, if your product is needed to be kept at minus 2 degree centigrade, definitely there may be a situation where phase change may come up. So, there, that heat of fusion or heat of crystallization or heat of solidification this part of water in the product will come up, right and again I am not saying it to be a completely unsteady or steady, because if you, if you put them into that bracket, they will never come to steady, or never come to unsteady. Because, sensible heat, while bringing down from 40 to 20, or even low, if you bring down to 40 to 10, or even lower, during that transition of 40 to 20 or 10, is the unsteady. But, once it reaches, then also it is a sensible heat which is required to be taken out to maintain the temperature, because it is m C p delta T.

So, that is under steady. So, that is why, but, we can say that in the beginning, these are all unsteady, right, but that fusion of water or solidification of water, so, that is perhaps, steady one because though it is a function of temperature, but still once it is reaching that point then it is a steady one. Other things are like heat in leak through the walls of the enclosure right. The house where you are at the very moment if you have in your room air condition then in that room walls are there, windows are there, doors are there. So, from if they are closed even then there will be because your room inside maybe say as we said 20, 24 outside maybe 35, 40 or whatever temperature.

So, this delta T is always there and because of that the wall it has a conductivity though low not only wall, but if you have insulation in many houses or many places they provide insulation to minimize the load. Whatever be if it is a wall or if it is a composite like wall then insulation then concrete everything they will have one resultant conductivity right. So, there you can find out from U A delta T, U is the outside heat transfer coefficient, overall, A, you know, delta T you know, because outside temperature is known inside temperature is known. So, you can find out. So, heat in leak through the wall, this is a steady one, right.

Why I am saying steady? You may say, sir, we have started from 40 and you are saying it to be steady. 40 to 20, it is taking time, it cannot be just like that, yes, can be also made just like that through different ways of cooling that is different, but otherwise it will take time. So, during that period that U A delta T, U, which you are saying, outside may be 40 and inside, starting from 40 to 20, it will take a little time. So, for engineering calculation purpose, we assume it to be that it will come to 20 and then this becomes a steady load, yeah, during the transition from 40 to 20, it is unsteady absolutely right and you will see that in many houses there are cracks or crevices. So, they will also incorporate some part of the load, but again it is a steady because that cracks and crevices, they are already there, unless you repair, unless you do something, it remains.

So, it is under steady condition. Different heat of condensation of moisture infiltrating into the enclosure, this comes of course, under say, storage preparation. So, there, it may have, if you look at every store is having a moisture barrier, because if moisture barrier is not there then the insulation will be affected by the moisture and insulation property will be more or less lost or minimized. So, there is a vapor barrier, but even then from the product, from outside, some quantity, of moisture will come and they will be more or less coming to the evaporator right. I told you in a household refrigerator there is the evaporator coil down below.

So, that evaporator coil which is there, if you start today, fresh the coil, you can see, it is dry, but maybe after 7 days of use, you see the coil, there is some ice already formed, Right, where from this ice came? This ice came from the products, from opening and closing the doors, from outside air. So, all these put some moisture, they will deposit onto the evaporator coil right. So, that is to condense it or to transform it from vapor to solid ice there will be some latent heat of condensation. So, that will be a steady load. Heat generated inside the room if there be any.

There are many ways of generating heat like in this room you see the light you cannot see the light, but these lights are on and they are having lot of wattage some are 100 some are 150 or 200 so much wattage. So these are all adding. So, if you have 10 such bulbs then 10 into say, on an average, 100. So 1000 watt you are constantly offering to the cooling load, right. So, what we need? We need to calculate, we have already talked about the types of loads we have said it to be either steady or unsteady.

Unsteady in the beginning and after sometime when it comes to steady then all becomes steady, right. I was talking about respiration. The product respire like we respire, we are also living, and I am not going to that how respiration cycle is working because that is beyond the purview of the course, but since you as I told that as and when I see that new thing is coming I just cannot remain silent because it is you who is getting information you are learning. So, how does it matter if I tell you if it is beyond the course if it is beyond requirement how does it matter? If you know it is always good because knowledge is all the time the best wealth, the best wealth is the knowledge. So, what I was saying that heat of respiration that we are respiring suppose in this room all the students are there.

So, all the students are respiring each of them, you, me, everybody. If instead of ourselves if there are the product or produce then also that is respiring. The best example is potato because potato is kept almost 8 to 10 months in the cold room right. So, it is respiring at that and this respiration is also a function of temperature. I do not know how many of you have gone to high altitudes, high altitude, I mean say Kashmir or say Ladakh, kind of Darjeeling, these are generally considered to be high altitude because there the temperatures are also very low maybe somewhere 5 to 8 degree or even lower somewhere it could be less than 0 depending on the time.

Now if you are going, if you are going from sea level, where temperature is very high compared to this high altitude you will see your respiration rate has gone down. Another best example it can be that I hope all of you do play whatever you may play football, cricket, badminton or any other anything. So, there you are running badminton or table tennis except Carom and of thing where physical movements are not so required, basket everywhere you are running around and lot of sweating you are having and if you just remember during that period your respiration was very high or if somebody is running say 100 meter or 1 kilometer whatever be then this sweating is also increased as well your rate of respiration also is increased. That means, rate of respiration is a function of temperature also, right. So, the one which we have kept in the cooling system at the beginning, whatever respiration rate was there, if steady state is arrived, or achieved, according to your desired set temperature, we said 20, 10, 0, minus 10 whatever be.

So, the respiration rate also will go down. It is a function of temperature. So, it will also come to steady only when the desired temperature is achieved, right from plus 40 to minus 10 degree suppose then it will take some hours of time or days of time depending on the size. So, depending on the size of the entire thing it will take couple of hours to couple of days to weeks because it is a volume also which is important. So, once it comes to the desired set temperature then it will also respire at the constant rate of according to that temperature, right that is why I gave the example of running.

For example, another one, suppose a mad dog is after somebody, I do not say you after somebody, then what he or she will do he or she will start running like again a mad, because of afraid of getting bite from the dog and that time if you just calculate or see the rate of respiration of that person is one of the highest because that time he has to avoid the dog for which running like anything was required, right. So, it is a function of temperature and respiration becomes steady once it attains the desired set temperature ok. So, with this we conclude today's class next class we will start looking into how the loads are calculated. Thank you.