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

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Lecture 56
Use of Phase Change Materials (PCM)

Good afternoon my dear friends and students. We have finished one of the major applications, that is freezing right. Now, we come to another very modern one, which is coming up. I do not say that, it has come up, it is coming up, that is, use of phase change materials. So, what do you understand by the term, phase change materials? See, in the previous classes, you have come across freezing, and freezing is a phase change process. So, there, we have seen, water is getting changed to ice, and ice is a phase changed material.

And in many cases, we have seen that, ice is used as one of the refrigeration system, for transporting many materials, right. Similarly, nowadays, instead of ice, many other things, because ice also has certain disadvantages, like, it is always, when it is getting melted, water is obtained. Now, if it becomes watery, then there are many systems, which are not suitable for using ice, as transportation system, for which, in modern days, it is of course still under research condition or still research going on to commercialize. But, someday, obviously, it will be, because it is also a system, where you are handling with materials.

So, selection of materials is one of the prime factor. Just you think, in this way, ice, you know, it is having a latent heat of how much? 335 kilo joules per kg. So, 335 kilo joules per kg, ice, that is, a huge quantity of heat, which you are getting, but, because, again, as I said that, ice, the problem is, when it is melting, it is also causing watery, all around. There may be some systems, which it is suitable, for example, when, in India, when fish is getting transported from one part to other, it is mostly by ice. Because, if ice is melted to water, fish will not have that problem, but, you imagine, something, where, your water is not allowed to touch that product, then, it is not possible to transport with ice, directly in contact, of course. But the moment, you have again ice as a primary refrigerant, and it is cooling somebody else, who is in turn cooling somebody else, then, a lot of heat transfer, heat losses are happening.

So, consumption will go very very high, that is not also desirable. To overcome this, researchers are looking into the application of phase change material, which, is our this classes talk, right. So, use of phase change materials, for application of food, and other things. What we understand by phase change material, that is PCM? It is just like that; it is in a cycle. How that the temperature of the material gets lowered or falls? So, you are obtaining a PCM, which is solidified, heat energy is released back into the environment, and it may do capsulation, encapsulation etc. that is separate part.

But, in general, so, you are getting that PCM material, where, temperature is rising because it is giving away the heat or cold to the other in a particular case. So, when you are transporting something, see, you are transporting this material from here to there. So, it is supposed to be at certain temperature, and that is maintained by say, a neighboring system, which is under phase change condition. So, that phase change material will give in turn to this and you are obtaining a dry transportation system, right. So, the temperature rises and then, again it is becoming liquid or semi solid depending on the material.

So, as PCM absorbs heat energy, it liquefies again, that the cycle is going on, right. So, it is, that means, heating and cooling and heating cooling and heating, this cycle is going on. As I said, yes, ice has a temperature of 0 degree centigrade, right, but, if you have some material, which can be solidified at say, minus 12 degree centigrade, and is solid, and it is having a high latent heat, then it may be very useful, because, if it is liquid, may be at higher temperature, may be say 10 degree centigrade, it is liquid. So, from minus12 to 10 it is giving the latent heat, and latent heat being high, so it can be utilized accordingly, judicially, right. So, this is the basic of the phase change material, and what is that? That is, you have to have some components, which may be liquid at higher temperature, it may contain in some container, and that is first phase changed, and then after changing of phase, it is solidified and that solid is giving the latent heat, and may be little sensible heat also, depending on the temperature of the phase change material, and then, it is liquefying and after that again it is coming back to solid.

So, these, to and fro of the heat for solidifying and getting liquefied by exchanging heat with the material, to be taken care of, that is, what is the prime principle of the phase change system, right. Now, three major factors that qualify phase change material. Now, phase change material can be reused for a number of times with same capability, this is one very good advantage. Second, it releases or absorbs energy, while maintaining the constant temperature, as we said, when it is giving away the latent heat, so, the temperature is constant and compared to other material, it has high latent heat storage capacity, that is what in the beginning I said. You have to select the material, whose latent heat is very high right. So, here, one such, this is water, this is stone, this is wood, this is plastic and this is phase change material, if there be a delta T of 15 K right.

So, it is most likely that, this phase change material is very much useful, having high latent heat energy storage capacity, right. This is one such consistency in performance over substantial number of cycles, this is how it is not very up and down. Then, heating without Pcm will be like this, if this is the melting point of the material. So, temperature remains constant during melting. So, like that and heating with Pcm will be like this. So, this is again further explanation of the Pcm or phase change material.

Now, if we look at classification of the phase change material, we can say that, phase change material, that can be classified as, whether it is organic, or inorganic or eutectic, right. If it is under organic, then, whether it is paraffin, or non-paraffin, or if it is inorganic, whether it is salt hydrated, or metallics. And for eutectic types, it could be organic, organic eutectic, it could be inorganic, inorganic eutectic, or it could be a combination of inorganic and organic eutectic. Eutectic, in the previous class, I have said, right. In a solution, you have the solute right, and depending on the eutectic temperature, or eutectic point, it can go up to that, for sodium chloride, we had shown that it is minus 21 point something ºC, right. So, that is a purely inorganic one.

Similarly, organic one also, we have said, about sucrose, if I remember correctly, so, it was around minus 12 degree centigrade, so that is organic. So, we can classify phase change materials in this way that, phase change materials can be organic, can be inorganic or eutectic again if it is organic it could be paraffin, it could be non-paraffinic material also or again salt hydrate I hope hydrate you understand, right. Like, say sodium chloride NaCl, I am not sure about this hydration number, say $2H_2O$, then, it is called hydrated sodium chloride. If there is no H_2O, associated then, it is called anhydrated sodium chloride. Just for example, I have given, it may not be chemically or chemistry wise right, right, because, I am not sure at this very moment, whether sodium chloride is hydrated, or anhydrated, perhaps, not some other material we can take, right, and association with the water molecule is hydrated and association without water molecule is anhydrated ok.

Then, we come to eutectic point, or eutectic temperature, which, we have already said, right, that definition, we have said, but for a recapitulation, we can say as the freeze concentration process progresses, solutes reach or exceed their respective saturation concentrations, and simultaneous crystallization of ice and solute becomes possible, right. The temperature at which a crystallized solute can exist in equilibrium with ice and the unfrozen phase is known as the eutectic point, or eutectic temperature of the solute. So, as we said, sodium chloride minus 21.13, sucrose not 12, minus 14, glucose 5, sodium carbonate minus 2.1, minus 5 glucose. We can say that melting point, how we can determine. So, melting point determination is also one part of the phase change material, right. So, experimental setup could have been that, you have one, you see, insulated thermocouple container or thermocol, rather, thermocol container, like this, and there is also one metal container inside of it. It has a thermocol cap over it. There is a data logger or data taker, whatever we call, and thermocouples are like this, connected to the temperature, which is to be found out right. So, this is then taken to the data logger and that is decoaded by this computer system, and from there you can find out the melting point easily.

As I said, this is under research still. So, there are some systems, like this, to determine either melting point or freezing point etc. Now, definitely if water is used as a PCM, or phase change material, then what we can see that, heat energy is transferred into the ice, then, the heat is used to break the bonds between molecules, not to increase the average kinetic energy. And since the bonds among the ice molecules have been broken, water is formed, the water molecules, at this moment, have the same average kinetic energy, as they did, when they were ice. And next, since the ice and water molecules both have same average kinetic energy, they are at the same Kelvin temperature, right.

So, if it is water as phase change material, right, but for others, some more information about the water as PCM is, like that, this is the solid PCM, ok, this is the liquid PCM. So, cold energy is supplied and this also so, this is by emitting and this is by absorbing, right. So, thereby, we can find out the melting temperature, Tm, right as we said, it is 335, no 334 kilo joules per kg right. So, 1 kg of 0 degree centigrade, this is also 1 kg of 0 degree centigrade, but, this is 1 kg of 80 degree centigrade, right. So, we can find out, from this type of curve, that is, the time temperature, which may be obtained by several instruments, which have come up nowadays.

And we get the melting temperature is somewhere point, minus 0.015, since it is experimentally found, melting point of ice is minus 0.01. So, it is approximately, 0 degree centigrade, right. So, that can be determined, with the help of the instruments, equipments, nowadays available to different labs, right.

Then, ethylene glycol as PCM. If we look at ethylene glycol can be also used as a PCM, since water can be used as PCM, ethylene glycol also can be used as PCM, right. Then, its melting temperature is found out to be minus 12.871 degree centigrade or roughly, say, minus 12.9 degree centigrade, right. One thing you are observing, water is melting point, we have seen somewhere 0 degree centigrade.

This ethylene glycol has a melting point of minus 12 degree centigrade. Obviously, which one will be a better PCM material? Water, because this is at minus 12.9, is the melting point. So, by the time it is coming to minus 13, or minus 12 degree centigrade, it gets melted. So, again, so, at the sub 0 level, you are working with which may not be desirable.

Now, it comes to the selection of the PCM materials. Definitely, as you see that, between the time temperature, and air temperature, air also, time and air temperature. So, one says, top temperature, this one, this is, says middle temperature, this one, and this is saying bottom temperatures, this one, right. So, temperature range, if it is 3 to 6 degree centigrade, air temperature profile inside a storage chamber, if we look at, if that be the profile of air temperature, this way obviously, your obviously, you have also said, this in our in our CA storage right. So, you can control within a limit, right. This will vary, like this in our CA storage also, temperature was varying with plus minus, maybe 1 degree, like that exponential 1, right. Because, you have to also depend on the sensors, and the recorders, or the receivers, its efficiency, right.

So, this could be a one, which is for air. Now, if we use polyethylene glycol 400, there are many, as I said that, lot of research is going on, and this is fundamentally the material selection, fundamentally, because, we have already said, how the PCM is working, right. If we know that, PCM, how it is working, then that means, PCM is extracting heat from the material and thereby changing its phase, whereas, the material is remaining at the desired temperature. So, there are many, when you need to take eutectic, we have also said, at given the example of many. So, depending on the material, so, one such, it is polyethylene glycol 400, its properties are like that, it is colorless liquid at room temperature, low toxicity, that is also required, melting temperature is 5 degree centigrade, and the formula is like this, molar mass is 380 to 420 g per mole.

Density is somewhere 1.124 to 1.126 kg per centimeter cube, and latent heat of fusion is 150.98 kilo joules per kg, obviously, much lower than that of the ice, but, still it could, because its melting point is high, so, it could be one of the user, or it can be used effectively. Then, say how we are finding out experimentally, right, obviously, data recorder through computer and this is a say, the box, where you are keeping your material to be tested. Thermocouples are used. There are many places, where thermocouples have been used, right, in the right place. So, this way you can monitor, we have been monitoring that, how the PCM is using, obviously, I cannot tell you the name of this particular PCM, as I said that, these are under research work. So, cannot be disclosed, but the inside of the material, which I had shown, the previous air temperature, right, inside of the material, how it is being calculated, how it is being experimentally found out, that I am showing it here, ok.

Then before I say thank you, because time is also over, before I say you thank you, what I would like to exchange with you is that, this phase change material being very very new, is not more than few years, may not be even a decade, the prime attraction or prime consideration is being given, such that different phase change material, one thing, we have to keep in mind, it should have high melting point, and high latent heat. These two are the fundamental, melting point should be high, and latent heat has to be very high, then it can serve as a phase change material very well, and the sooner it is discovered, or it is found out, comes in the market, many many materials will have very good transportation and the temperature can be kept that it desired one, ok. So, with this, I thank you for listening to this class. Thank you very much.