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

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Lecture 13
Basics of Thermodynamics Contd.

Good morning. Hopefully, you have gone through the previous class where we stated about the thermodynamic equilibrium as well we said about the laws of thermodynamics. We said there are 4 laws, zeroth law, first law, second law and third law and we said also that zeroth law deals with temperature, first law deals with internal energy, second law deals with entropy, and the third law deals with the absolute zero cannot be achieved right. So, out of which, we finished perhaps the zeroth law, and we said in subsequent classes we will go to first, second, third, all these laws and from there we will also find out some other properties, which we have not said as of now. Now, this is again continuation of the basics of thermodynamics, it will take a little time. As I said earlier, and then we come to the first law right.

We come to the first law of thermodynamics after zeroth law. So, if some heat or work is added to a system or removed from the system either adding or removing. So, if we do that, then none of this is created or destroyed in the system right. So, according to this law, perpetual motion machine, perpetual motion machine of the first kind, which can be, which can be abbreviated as PMM, is impossible right, perpetual motion of the first kind is impossible.

You have seen the toys during your childhood right. So, in that toys what did you do? Say, if it is the toy then you put some spring and give with the key something, right and the toy, say, if it is a, if it is a car, then, it goes on, right and you are happy, but it goes on till when you had given the energy, by, in the form of that key right. So, it cannot be that, after that, it will also go on running, that is what is the perpetual motion of first kind and this is impossible. So, in other words it can be also said that heat and work these are inter convertible. So, heat can be converted to work or work can be also converted to heat and this is governed by the equation that is called dU is equal to dq or dU is equal to dQ minus dW, right.

So, that d is small, by chance, it has, it has come capital and many cases you know, nowadays, systems do change according to is wish. So, might be it was not properly looked into. So, this is dw. So, dq is equal to dU minus dw this is the first law, right and this means, if work is done by the system, which is considered to be positive, as we said in earlier class, and that is dw positive, the internal energy dU will decrease, since, work will be done at the expense of this internal, energy right. So, in other words we can also say that if dq amount of heat is transferred to the system, which is considered to be positive, as we said, this is positive, then internal energy dU will increase.

$U_2 - U_1 = Q_{1\text{-}2} - W_{1\text{-}2}$

$$m(u_2 - u_1) = Q_{1-2} - W_{1-2}$$
$$or, u_2 - u_1 = q_{1-2} - w_{1-2}$$

This means, internal energy increases, if heat is transferred to the system or work is done on the system, either heat is transferred to the system or work is done on the system then internal energy is increasing right. Of course, internal energy, means the sum of all total energies, total of all forms of the energy, such as it can be nuclear, it can be atomic, it can be molecular, it can be vibrational, it can be rotational, it can be lattice, or thermal, etc, as many you can, all forms of energy together is giving you the internal energy right. So, we have come to know that dq is equal to dU minus dw right. Then if the initial state for a closed system be 1 with an internal energy of U and if q 1 to 2 right, q 1 to 2, this is, that is state point 1 to state point 2, q 1 to 2 in kilojoules of the heat is transferred across its boundary then, w 1 to 2, w 1 to w 2 kilojoules of work is done by the system reaching at an equilibrium state of 2, from state point 1 to state point 2 right. And, in that case, we can say that u 2 minus u 1, is equal to q 1 to 2 minus w 1 to 2.

So, if m dot is the mass of the system or m is the mass of the system, m dot normally used for rate, any rate means, per unit time. So, here if it is mass flow rate then m dot, but if it is mass of the system m is the mass of the system and u denotes the specific internal energy again whenever the word specific will be used, it is normally per unit mass, right specific energy, specific, any other thing that will be per unit mass right. So, u denotes, small u denotes specific internal energy of the system in kilojoules per kg, then m into u 2 minus u 1 is equal to q 1 to 2 minus w 1 to 2 right. It is per unit mass, right or if it is divided, no this is not per unit, this is the whole right and by chance it was a capital U and this is also capital U, U 2 minus U 1 conventionally like this Q is capital, this W is capital, conventionally, when it is for the total mass then, it is capital when it is per unit mass, then it is small this is by convention, right. So, we can write that m into U 2 minus U 1, this u's are capital is equal to Q 1 to 2 minus W 1 to 2, or we can also say that u 2 minus u 1 small is equal to q 1 to 2 small and minus w 1 to 2, small, right.

So, where this q 1 to 2 or w 1 to 2, that heat and work, heat transfer and work done per unit mass of the system, that is what I said that when it is in small letter, then it is per unit mass, but when it is in capital letter, then it is the total mass, or for the total mass, we should say, right. So, we got u 2 minus u 1 is equal to q 1 to 2 minus w 1 to 2. Now this is an open system right. So, we have v 1 A 1 right v 1 into A 1 v is the velocity in meter per second and A is the area in meter square right. So, it is meter cube per second that is volumetric flow right.

So, that is volume flow. So, if we know that v 1 into A 1 is equal to m dot into v 1 that is m dot is again mass per second or sorry this is only mass into into v is meter per second right or mass is kg. So, that becomes kg meter per second right. So, if this quantity of the system, your system is coming here in a time delta t, right in a time delta t through the area A 1 from the state point 1 through the open system at a velocity v 1 at a pressure of p 1 coming to the state point 2 where the velocity is v 2 right rate of flow of work is equal to d w d t and that is m p v 1 under the area A 2, then we can say work done in time delta t is, d w and that is equal to force into distance and that can be equated to p 1 A 1 into v 1 del t right or we can write p 1 A 1 v 1 del t, that is the work done in time delta t, right. Now, another thermodynamic property comes up, that is called enthalpy, of course, we know, it is not that you may not know, but you may be knowing that enthalpy.

So, enthalpy is the combining specific flow work that is p 1 v 1 with internal energy u 1 at the inlet and subsequently at the outlet, we can get enthalpy h, by convention enthalpy is used either small h, or capital H right by convention it is used either small h or capital H. So, H is equal to u plus p v right. So, H is equal to u plus p v therefore, for an open system, where flow of work is to be included, enthalpy is considered in place of internal energy, H is equal to u plus p v, keep in mind right, Subsequently we will be using at many places. So, where we may not be able to trace back or go back. Now after the first law we come to the second law of thermodynamics and in that we start with Clausius statement right.

What is Clausius statement? It is saying, it is impossible, it is impossible to transfer heat in a cyclic process, from low temperature to high temperature without work from an external source. It is impossible for water to flow from a low height to an upper height without any external source, like pump right. So, the same thing is being said that, it is impossible to transfer heat in a cyclic process from low temperature to high temperature without any external source. All the energy supplied to a system as work, can be dissipated as heat all the energy supplied as heat, but, it cannot be continuously converted to work with a thermal efficiency of 100 percent. All the work can be dissipated as heat, but all the energy supplied that heat cannot be continuously converted to work with a thermal efficiency at 100 percent.

Otherwise, an automobile will run by driving energy from atmosphere, or a ship can flow or propel itself by deriving energy from the ocean right. So, what Clausius statement is saying, that you can convert heat to work with 100 percent, but the reverse work to heat even the efficiency is 100 percent cannot be achieved or cannot be done, that is the prime thing which the Clausius statement is describing right. Example is given as otherwise automobile would have used air from atmosphere as the source of energy and it would have been continuously flowing or say, ship could propel using the ocean as the energy source. So, these are not possible. So, that is what Clausius is saying.

We can convert heat to work completely, but work to heat completely is not possible right. So, this leads to a hypothetical machine of perpetual motion of second kind that is what is the statement, that perpetual motion of second kind is impossible right. That means, that all the time you will be moving without any support of energy that is not possible. Then another great scientist or not a, other scientists, they said, that is, Kelvin and Planck, they said that, it is impossible to construct a device or engine, operating in a cycle, that will produce no effect other than extraction of heat from a single reservoir and convert all of heat into work. I repeat it, they said, it is impossible to construct a device or engine operating in a cyclic process that will produce no effect other than extraction of heat from single reservoir and convert all of heat into work.

This means the higher the temperature of the heat source and the lower the temperature of this, heat sink, that is surrounding the higher will be the efficiency right, but is it possible that in one side you think that you have 1000 degree centigrade and any another side you have minus 100 degree centigrade even then that you can convert is it possible perhaps not right. So, this is what Kelvin Planck said. Now this brings us to another concept that is called reversible and irreversible process right. Reversible and irreversible process. By simple logic we know this is a irreversible sign whereas, this is to be a reversible sign right.

Yes, if we know the sign of reversibility or irreversibility, but what is that let us say. We say that, a process is reversible with respect to the system and surroundings if the system and the surrounding can be reversed to their respective initial state. So, if we start from this point 1 and come to the point 2 by this process now if I can go back to state point 1 then only we can say that this is a reversible process. We started with this, we came to this, and we returned to the same point then it is a reversible process, but if it is not that if we are not able to go back to point 1 then we call it to be irreversible right. Then a process is reversible with respect to the system and surroundings, if the system and the surrounding can be reversed to their respective initial state by reversing the direction of the process that is by reversing the direction of heat transfer and work transfer.

The process is irreversible if it cannot adhere to this criteria right. Then we come to another very important one that is which you are saying about the entropy. Now you look at if q 1 to 2 is heat transferred that q 1 to 2 is heat transferred and W 1 to 2 is work done on the system it will move from initial state point of 1 to a state point of 2. The internal energy of the system will change from u 1 to u 2 such that u 2 minus u 1 is equal to q 1 to 2 plus W 1 to 2. Now if the signs of q 1 to 2 and W 1 to 2 are reversed the internal energy will change from u 2 to u 1.

However, the system will not come back to the point 1 right the system will not come back to the point 1. And this is why we develop another parameter which is the entropy. So, it will not come back to point 1 unless the heat and work transfer are reversible. The first law is valid however, during the irreversible process 1 to 2 the description of state point 2 is not complete. Something has changed so that we cannot bring back the system to state point 1 by reversing the sign.

So, reversing the signs of both heat and work transfer. So, this is not reflected by internal energy, hence, a property is required to give the measure of this irreversibility right, and that is done by the property called entropy, right. Since we are not able to go back by reversing both the heat and work transfer to the state point 1 to 2 and back to 1, since it is not, if it is possible then it is reversible. If it is not possibility, if it is going somewhere else, then we call it to be irreversible, and since, it is not possible with the help of internal energy only to explain, this by reversing the heat and work transfer, we are not able to reach to state point 1 and that can be explained with the help of a new property, called entropy right. So, we have come across with a new property that is called entropy right.

So, let us stop today here and next day we will start using the entropy for maybe the Carnot cycle ok. Thank you.