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

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Module No 08

Lecture 36
Gas as Refrigerant

Good morning, my dear friends and dear students. Students are the dearest of all teachers, there is no ambiguity irrespective of teacher, students are dearest to them. Because, teachers do love to communicate to the students, not only that they want to impart some knowledge, whatever the teacher is having, right. So, though I tell in every class, in the beginning, that good morning and good afternoon dear students, really I love my dear students, not only I love my dear students, I also get love from my students, all over the world. You see, in every occasion, they do write to me, they do wish to me, etc, right. So, I am very happy that I am coming in across with you.

So, before I start, because after some days the classes, will be over, and then your exam will come someday, and the way you are seeing that these cycles are so big that if I give questions which are subjective, then what will happen? Because these questions are checked by computer, no manual checking. So, computer will check based on what information I have given. Now, the same thing you might have said, the Carnot cycle in your words and I have said the same Carnot cycle in my words. So, there will be a mismatch.

So, computer will take your thing 0, to avoid that our parent concern, that is NPTEL, they have devised such a beautiful, because over the years, I have been taking many many courses. So, they have made such a beautiful technique, that it should be objective type, right. So that, there is no ambiguity. It is unambiguous. So, that is why, it may not be possible for me to make questions, out of cycles, itself, but, it does not mean that from the cycle, or cycles, some internal things, I cannot ask, that I may.

So, it is very much required that, you go through carefully, otherwise you may miss which I do not like, I wish all of you get 100 out of 100, that exactly depends on how you are preparing yourself. You know, or by this time, that, there will be some weekly test, or weekly, some assignments given to you. I have my co teacher associate or assistant. So, they will look into them, and obviously, they, whose are also objective, right. So, if you go through carefully, you will be able to answer.

So, my request to all of you that, please do not take it lightly. If you are really interested to give the exam, there are many students, who appear, and do not appear in the exam, but, I have no idea why it is. Is it only for some 1000 rupees of exam charge. It should not be, nowadays, 1000 rupees, perhaps has no value, and you are getting a certificate, right and that will definitely carry throughout your life. As well this certificate, whatever the equivalent credit course, that make, be relaxed from your normal credit course.

If you are studying B.Tech, M.Tech, Ph.D, whatever right. So, this is my request to you all friends and students even including friends those who are senior, that, please go through carefully, and these videos are open to you throughout the day and night.

So whenever, you find time, you can go through, or you can study, you can refer some books also, right, though I have not given any reference as of now. Because, perhaps in the very first introduction, I have already said something please go through that, and I always refer my teacher who is no more, professor R.C. Aurora. There is a book on refrigeration by C.

P. Aurora, that is very old book, right. I am not saying, that is bad, that is also very good book, but very old problems are less etc. Professor R.C. Aurora, so this thick, the book, and it is also nice.

Unfortunately, perhaps, before editing it, completely he expired, and really, I mean, my greatest gratitude to him because, he was my teacher, right. However, now let us come to the subject. We have covered Carnot cycles. We have covered in the last class also if the substance is a pure substance right. Now, we will switch over to gas as refrigerant, right.

So, gradually, we are coming to the natural situation, from ideal to the actual situation, we are coming up. So, obviously, there will be some or other changes, so those will be definitely covered during the course, right. So, gas as refrigerant. If we look at that, this is what, that gas as refrigerant, and if you remember that, Carnot, which we had already said, many many times, right and this we call reverse Carnot cycle, right. So, the arrows are reversed than that of the Carnot refrigeration cycle.

This you can confirm from the figures, which is before you, that figure A is the actual and figure B is the that of the Carnot. So, Wc work is done on the system, Qc quantity of heat is supplied to the system, Wt quantity of work done by the system, and QL quantity of, that was QH quantity, which was coming and QL quantity of heat is rejected. This was the reverse Carnot cycle, right as it is shown in the earlier cases also. But, here what we are doing? In the actual case, there is reversal of the Carnot is, W C quantity of work is done on the system, the QH quantity of heat is rejected as from that condenser then perhaps, again this is a cut, and paste. So, this is an error.

So, it should be this, W T quantity of work done by the system, for which QLquantity of heat is introduced into the system from the evaporator, right. So, this is the difference between the Carnot and rest of the Carnot. If we analyze this, then what we get? This is the reason, as we said, why the cycles are called reversed Carnot cycle. So, and in both the cycles, the temperature to which heat is rejected is of course, the same, because there was also QH and QL, here is also QH and QLand the temperature was TH and TL, here also TH and TL, right. However this cycle consists of the following reversible processes.

Reversible processes are: like this, that step 1 to 2, right step 1 to 2, I go back to the original figure, so that it becomes easy for you, that, this was, so step 1 to 2, we mean this step, right. So, 1 to 2 is that, or what I can do, this is the reversal, not that, mind it, this way, ok. So, there, we can say, we can say, that,this is a, this is an isentropic input, WC in a compressor right, isentropic input in a WC as WC in a compressor, right. So, instead of going to and fro, again, as in the previous classes, I had shown you that, we have this dome, right and in this case, it is also reversible, but one thing, let me check that, yes, it is that, this is the 1, oh, oh, this is the 1, this is the 2, this is the 3, and this is the 4. So, WC work is done on the compressor, 1, 2, 3, 4, WC work is done on the compressor isentropically, because, entropy is constant, this is the entropy.

So, it is isentropically, WC quantity of work is given, as input to the compressor. Then, step 2 to 3 is isothermal heat rejection, that is QH to a heat sink. So, from here QH quantity of heat is given to the heat sink and finally, it will come, QL quantity of heat is supplied to the system, right. Therefore, we are, we are giving away QH quantity of heat to the surrounding through condenser, right, and that is the heat rejected at the temperature constant, because it is isothermal. So, at the temperature TH, it is rejected.

Then, step 3 to 4 is again, an isentropic work output WT, right. So, WT, this is done by the turbine, right. It is done by the turbine, it is work output, that is the work done by the compressor, or turbine, in this case, right. And the fourth case is step 4 to 1, that is, isothermal heat absorption QL at temperature TL, TL temperature, QL quantity of heat is supplied to the system, right. Then, we have summarized it, and the theorems are similar to the Carnot theorem and these are: no refrigeration system can have a COP greater than that for a reversible cycle working between the same two temperature reservoirs or sink and reservoir.

So, it is TH and TL. Then, all reversible cycles operating between the same two temperatures of receiver and sink have the same COP. This also, we have proved earlier, right. All reversible cycles operating between the same two temperatures of receiver and the sink have the same COP. This also,we have done explicitly earlier, right. Now, the other way we can say, the COP of reversible cycle is independent of the working substance.

This also we have said, and proved earlier right. So, this is already established. Now, using the first and second law of thermodynamics in this, these theorems can easily be proved as like this. So, let us consider the figure, as shown below and the figure is this. We have one refrigerator, and we are having rather.

QH as the heat source, QL as the cold refrigerator. So, as you see from here that, QL is the cold refrigerated space at low temperature TL, and QH is the one environment at temperature TH, right and W quantity of work is done on the system, right. So this we can say, a refrigerator removing heat, QL from a cold space. So, we can write, from this figure that, W is equal to QH minus QL, which is, earlier also, from the first law, we have seen. The Clausius inequality from the second law of thermodynamics, that states that, integral of cyclic process, integral under cyclic process of dQ over T is always less than or equal to 0.

This was Clausius inequality statement. In thermodynamics, we had said this, right. We had established also that, this integral of cyclic process dQ over T is less than equal to 0. So, if that be true, then what we can say that, the cycle or cyclic integral is 0 for the reversible cycle, and less than 0 for the irreversible cycle, that also we have said earlier, that for the reversible cycle, for a cyclic process, the integral is equal to 0 that is dQ over T is equal to 0, and dQ reversible over T is 0 and it is less than 0, if it is irreversible, right. So, by convention, we have seen that, heat transfer to the system is considered to be positive, heat transfer to the system is considered to be positive, and heat transfer from the system is considered to be negative.

So, this means Q L is positive, and Q H is negative. If you remember that, sorry, if you remember that, our system was this, right. Our system was this, and Q L quantity of heat was subjected to this, and Q H quantity of heat was rejected right. Since Q L is applied to the system, we call it to be positive and Q H is rejected from the system, is negative right. So, we can say that, Q L over Q H, rather Q L over T L, is minus Q H over T H, is also less than equal to 0, right, is also equal or, less than equal to 0, and hence, from the above relation we can write that, Q L over T L minus Q L plus W over T H because, Q H we have already shown.

If you remember, in the previous equation, we had shown that, here that, W is Q L sorry W is Q L, Q H minus Q L right. So, this already we have done. So, we can say that, we can say that Q L over T L minus, now instead of that Q H, we are writing, Q L plus W, right over T H, and this is also less than equal to 0 right.This is also less than equal to 0. So, we can say that, Q L into T H minus T L over T H, T L minus W into minus W over T H is also less than equal to 0.

So, from here we can say that, the COP is, as defined that, Q L over W, you remember, I said, how many paddy how many rice, that is the COP, or efficiency, from how many paddy how many rice you are getting. So, that is the COP, that is the efficiency, in every step of life, here also how much work you have given as input and how much refrigeration effect Q L you have received, this ratio is the COP. So, this is also less than equal to T L over T H minus T L right. So, from that we can say that, this relation states that the COP of reversible cycle is the maximum, because, irreversible is less than 0. So the COP, for the reversible cycle is the maximum, and the proof of the first theorem is this, that the COP is maximum for the reversible cycle for irreversible it is less than that right.

So, that we have already showed here, that is less than equal to 0. This is also less than equal to 0. So, that equal to is for reversible, and less than 0 is for irreversible, right. So, our today's time is up so we will meet again in the next class. Thank you.