INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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NPTEL ONLINE CERTIFICATION COURSE

Refrigeration and Air-conditioning

Lecture-03
Air Refrigeration Cycle

with
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I welcome you all in the course on Refrigeration and air conditioning today we will cover the air refrigeration cycle in today's lecture we will covering Joule Barayton cycle Brayton cycle.

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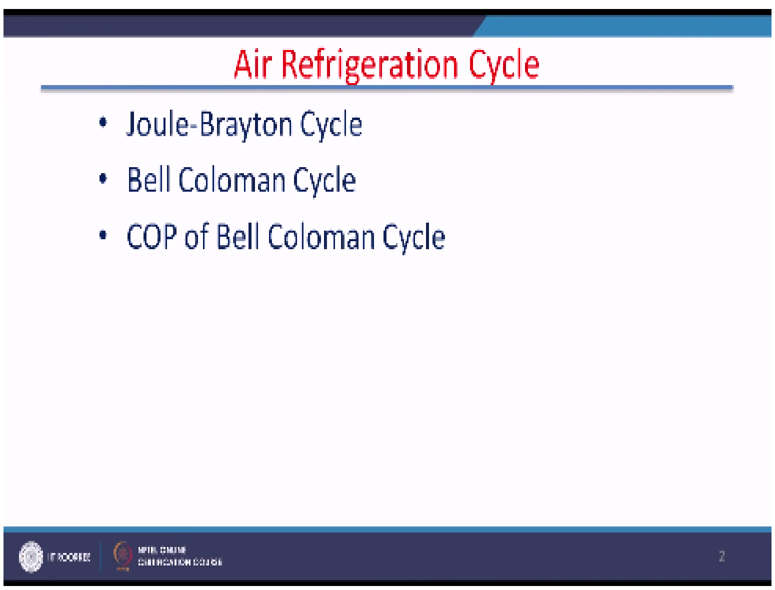

And we will try to find COP of bell Colaman cycle the starting with the Joule Britain cycle I actually Joule Barayton cycle is a years ended cycle for power generation and this cycle is being used for the power generation in gastro bias it is one specific application in gastro bias and in this cycle there are two isentropic processes.

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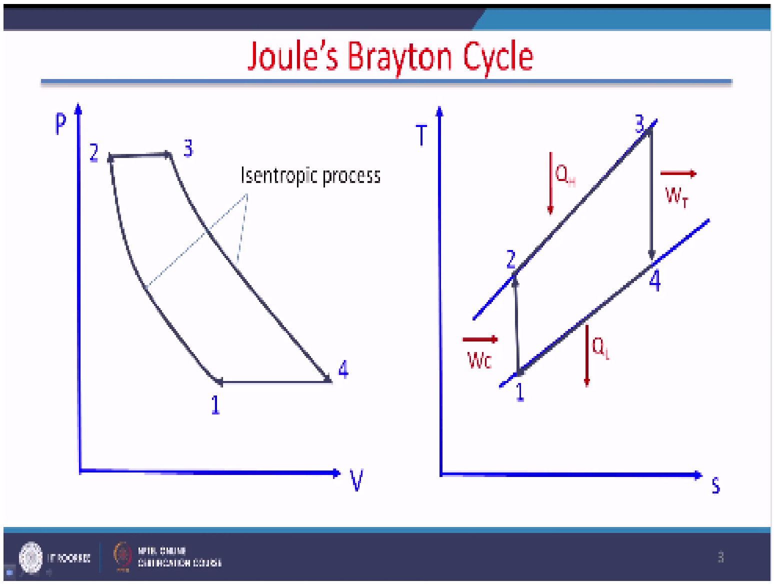

And where two constant pressure processes so this cycle is debited here on pressure volume diagram and at the same time this cycle also debited here on temperature entropy diagram now in this cycle first here is a working fluid and the first air is compressed from state 1 to state 2 through a compressor at state constant pressure heat addition takes place normally in the gastro bias separate compression chamber in that compression chamber the heat addition take place but since it is a air sender cycle the it is assumed that the throughout the cycle air is fluid so from state one to state 2.

Compression air takes place is state 2 to state 3 constant pressure heat addition takes place constant pressure heat addition to air takes place and when the state 3 attain the expansion of air takes and we attain the state 4 during this process the output the net output of the cycle is the area of PV diagram under 1, 2, 3, 4 this cycle can also be shown on temperature entropy diagram process 1 to 2 is isentropic compression where work is done by the compressor on the guest on the air process 2 to 3 is constant pressure heat addition process 3to 4 is output of trephine or expansion of hot air take place and process 4 to 1 is the cooling process or if it is open cycle then at state 4 the air is thrown to the surroundings now if you reverse this cycle if you reverse this cycle reverse means instead of expansion process 3 to 4 compression in process 3 to 4 3 takes place compression and then heat rejection then 2 to 1 expansion and 1 to 4 heating the cycle will become something like this now this is reverse Joule Barayton cycle or it is called bell Colaman cycle.

Bell Colaman cycle here refrigeration cycle it is called air refrigeration cycle because in this cycle air is the work king fluid or air is the refrigerator now in this cycle.

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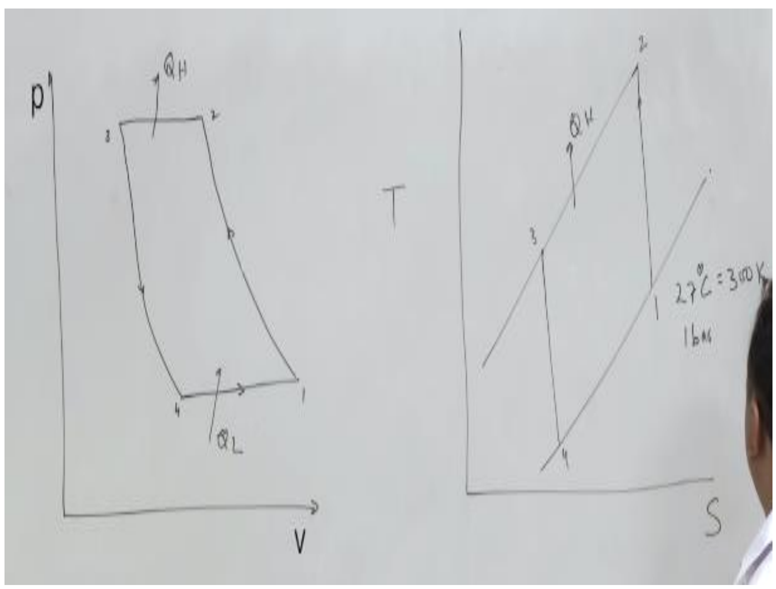

If we show it on the PV diagram firs of all compression of air take place from state 1 to state 2 after this compressing the cooling of air take place or heat is removed during this process from the air so the temperate of the air goes down when the state 3 is attain again expansion take place inside an expender it is a turbine or an expender where expansion takes place and these two processes 3 to 4 and 1 to 2 are isotropic process and 4 to 1 process where heat is taken from the surroundings and this process 4 to 1 process a the pulling effect, now if I want to show this same cycle on temperature entropy diagram.

Then the two constant pressure posses constant pressure lines process 1 to 2 isotropic compression where the pressure increases then heat is extracted from the sphere high pressure here so it becomes high pressure low temperature here and heat is taken away from here and we are in state 3 at a state 3 again the expansion takes place and state 4 is read, now I will give you some numerical values for this states also.

So that you will have fairly good idea about this cycle now starting from state 1 suppose here is a label at 27^0 C and one bar pressure so when air is available at 27^0C it is equivalent to 300 Kelvin of temperature, suppose this air is compressed in a compressor having compression reserve 4.

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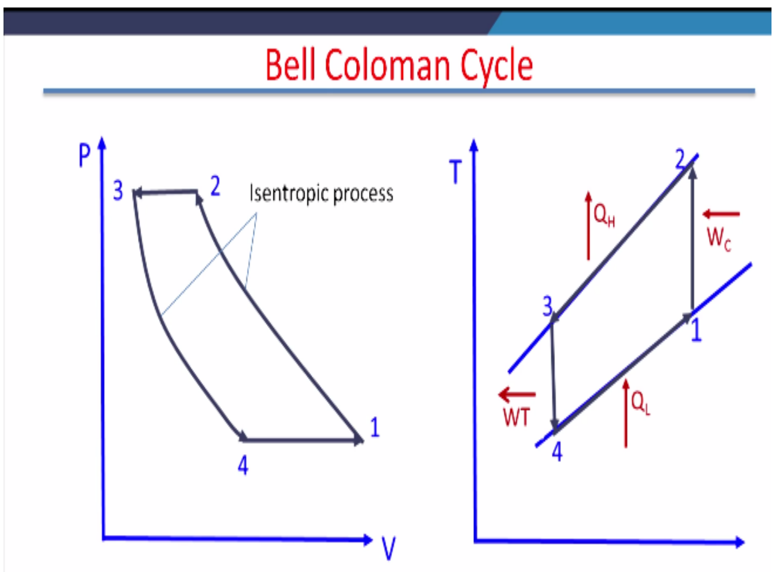

So P2 with P1 is 4.

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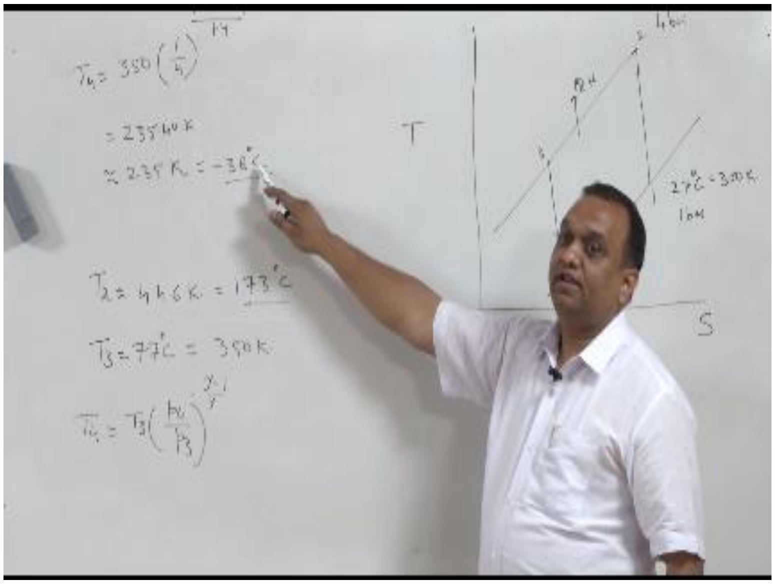

P2/P1, now temperature at state 2 is been to be P1 multiplied by $(P2/P1)^{\gamma-1/\gamma}$ because it is following the process Pv^{γ} =constant where $\gamma = 1.4$ for air, now if you put the numerical values that T1 is 300 Kelvin so in order to find T2, T1 is 300 Kelvin, P2/P1 is 4, $(4)^{1.4\ -1/1.4}$ it will turn out to be 4 approximately 446 Kelvin it is exactly it is 445.97 another zoom for 46 Kelvin so 446 Kelvin = 173^{0} Centigrade.

So the temperature of the air is increased where during the compression process 2.73^{0} C now if I cool this air with the help of surrounding a surrounding in is 27^{0}C, I cool this air to let us say 77^{0}C so it is T3 is 77^{0}C or 350 Kelvin, temperature of air a level at state 3 is 350 Kelvin and pressure is 4 bar here pressure is 1 bar here pressure is 4 bar, now if I expect this here 2 straight 4 if I expect this here 350 Kelvin here at 4 bar to one bar. Isotropically in that case I am going to get $T4 = T3(P4/P3)^{1.4-1/1.4}$ and this just a minute is raise to power $\gamma - 1$ over γ now P3 is 300 $T_4 = T_3$, T_3 is 350k 350 and P_4/P_3 is ¼ and 1.

This γ 1.4 – 0.4/1.4 so this will turn out to be 235 approximately 235.44k or let us say 235k or is equal to - 38°C so during this cycle during the cycle we have taken outside a compressed it who let and then we have expanded back to the seam pressure 1 bar and the temperature of here had reduce to - 38°C which is very, very low so with the help of this Belcolovin cycle we can get very low temperature in the case of here now after this we will find try to find the performance of the cycle in order to find the performance of the cycle.

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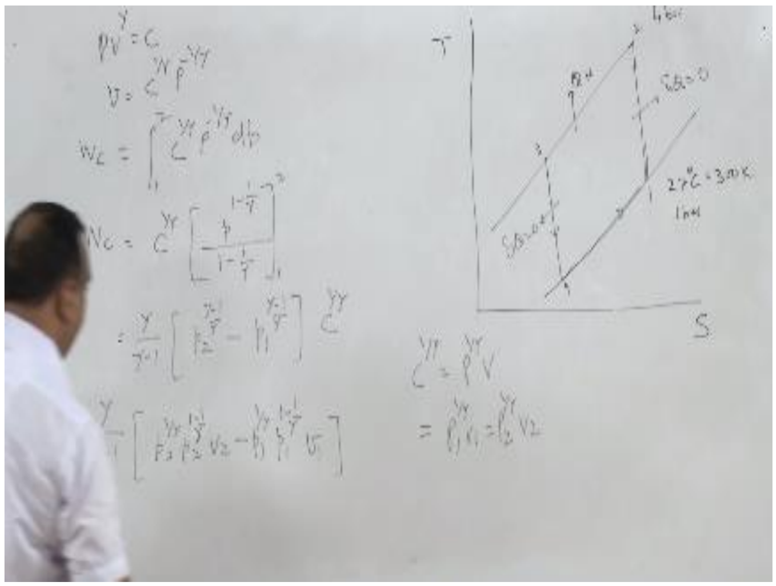

We should how much heat transfer is taking place and how much energy is consumed in compressing that here during the refrigeration process that is 4 to 1 but heat transfer is that is OL is CP this is constant specific heat of here at constant pressure $T_1 – T_4$ this is the refrigeration effect we are getting the cycle now how much work is consumed work assumed is AV of PV diagram or work in compression – work deemed in expansion now compressor work from state 1 to state 2 were several ways of doing it first fall it is a cyclic process so in a cyclic process as per the first law of thermodynamics.

Cyclic integral of δQ = cyclic integral of δw here in these two process, process 1 to 2 and 3 to 4 they are isotropic process so heat transfer is 0 only heat transfer is taking place in process 4 to 1 and 2 to 3 so net E transfer C_P $P_2 – T_3$ CP($T_1 – T_4$) and this net heat transfer is also network transfer that is one we have doing it another way is if we use the formula δw is integral of 1 to 2 Vdp through this formula also.

We can find the work done because when these process are not isotropic in that case we cannot use this formula this formula is applicable only in that is when all the process is are ideal and there is no heat transfer during these two processes. So in order to have a generalized expression let us try to find out work through this formula, work consumed by the compressor through this formula, this work interaction has negative sign an energy is consumed by the compressor it means work interaction is negative in this process.

So negative, negative is positive so for positive so the work of the compressor is state 1 to state 2 Vdp. During the compression if it isotropic compression or reversible automatic compression PV^{γ} will be remain constant or $V=C^{1/\gamma}$ and $P^{-1/\gamma}$ now putting these value of V here will get work of the compressor is equal to integral from 1 to 2 $C^{1/\gamma}$ $P^{-1/\gamma}$ db again the work of compressor is equal to $C^{1/\gamma}$ and if we integrate this will be getting P1-1/γ/ 1-1/γ 1 to 2 or γ over γ-1 $P_2^{\gamma-1/\gamma}$ $-P_1^{\gamma-1/\gamma}$ multiplied by $C^{1/\gamma}$.

Now $C^{1/\gamma}$ is equal to $P^{1/\gamma}$ into V, now putting this value because now PV now we can always take it as like this $P_1^{1/\gamma}V_1=P_2^{1/\gamma}V_2$ now putting this value of C here we will be getting γ/γ-1 $P_2$1/γP2γ-1/γ V2-P1 1/γ or we can instead of writing like this γ-1/γ I will write 1-1/γ, 1-1/γ and V_1. If you simplify this equation you will be getting work consumed by the compressor is.
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γ/γ-1 P_2V_2-P_1V_1 here it is considered to an ideal gas here so PV can also be replaced by RT so γ/γ-1 $R(T_2-T_1)$. Now γ/γ-1.R is nothing but CP, CP (T_2-T_1) here there is an interesting observation that automatic compression is taking place pressure of the gases raising, okay and work done in this process is CPδT, CP is the heat at it a specific heat at constant pressure, it is CPVP and there is no constant pressure process here.

So it is only N expression it does not indicate that the pressure is the process is a constant pressure process but this expression is a simple expression for work will like the compressor similarly we can find the worth output during process 4 that is work of the turbine or work of the expender it equal to Cp T3 – T4 and the network is cp t2 – T1 – Cp T3-T4 or Cp T2-T3 – cp T1 – T4 or heat rejected in this process. And heat take care in this process or cyclic integral of heat.

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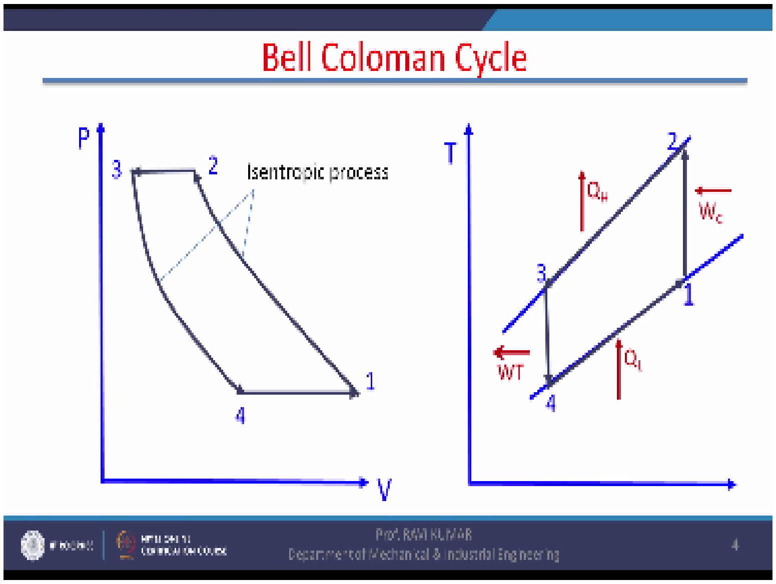

Heat transfer there is another way of I have already discuss two ways of idée the network there is another method also if we use the first law of open system first law of open system states.

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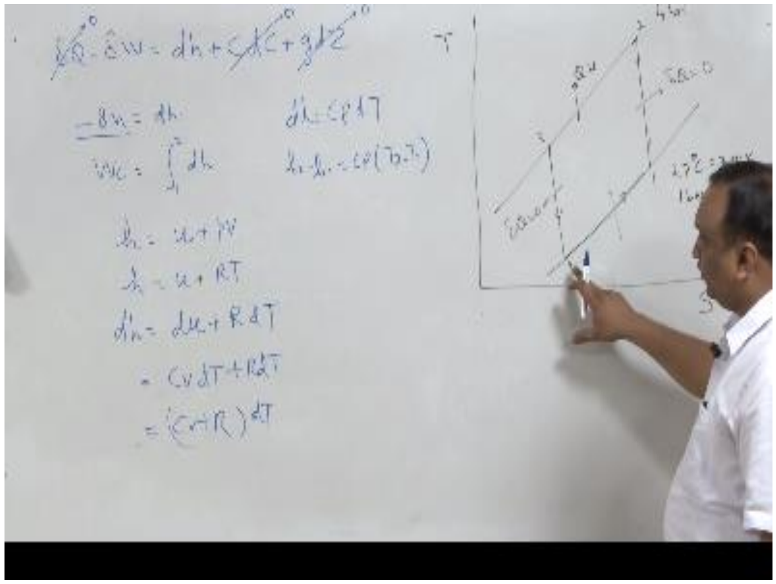

When in open system δ Q- δW = dh + cdc + g dz now here in this case in case of compressor this changing potential can be consider a 0, to change in kinetic energy is also 0 isentropic process there is no neat transfer, so –δw is dh this –δw means work is consumed b the compressor, so work of the compressor is integral of 1 to 2 bh as we know net h = inter energy + Pv or h = u +rt.

Pv we can always use the relation Pv = rt in case of ideal gas and here is an zoom to be an ideal gas so dh = du + rdt or du is always cvdt + dt and this is Cv + r dt and this is so dh = Cp Dt or h_2 – h_1 = cp t_2 –t_1 similarly we can drive for this also that work at in a during expansion process, C_PT_{3}-$T_{4,}$ and we can again come to the conclusion or we will come to the, same expression as we have attain through the earlier, processes, so we have there alternative methods, to find work during compression. Now COP of this cycle, coefficient of performance of this cycle, because efficiency of any refrigeration cycle is judge by the coefficient of performance, so coefficient of performance is.

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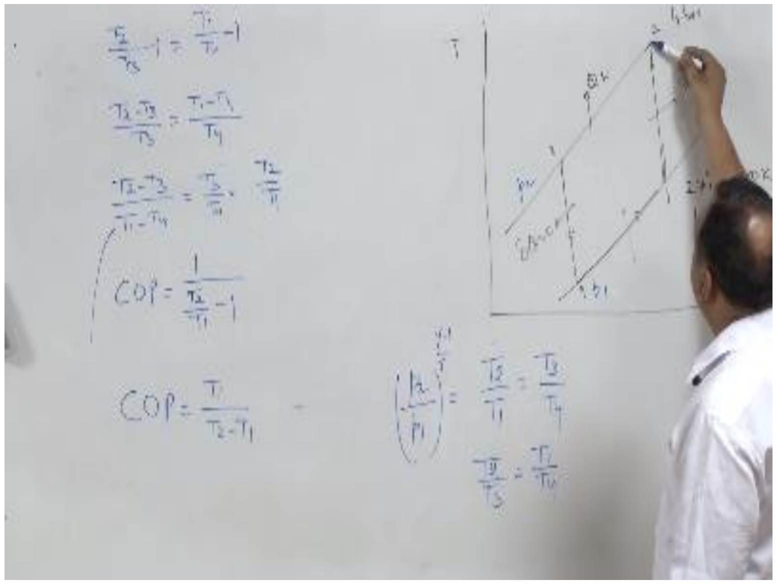

Heat transfer during the refrigeration process, that is CP (T1-T4) divided by network consumes, so it is going to be CP(T2-T1)-CP(T3-T4), CP will be cancelled out, and COP, will remain T1-T4/T2-T1-T3-T4, if we rearrange these terms, T1-T4=(T2-T3)(T1-T4), or it is equal to 1/T2-T3/(T1-T4)-1,we can further simplify this, because (P2/P1) $^{\gamma\ -1(\gamma)}$ =P2/P1, this is also P2,and this is P1, so P2/P1=T2/T1, this is from ideal gas relation, is equal to T3/T4,.

Now here if you take this relation, or we can further manipulate it like this, P2/P3=T1’T4, so T2/T3-1=T1/T4-1, T2-T3/T3=T1-T4/T4, or T2/T1, this T2-T3/T1-T4 can be substituted here and we can get the value of COP as 1/T2/T1-1 and final expression for COP as T1/T2-T1, so for ideal bell callable cycle, we need only two information, temperature after compression, temperature before compression and we can find the COP of the cycle. Actual cycle, now actual cycle, I will depict actual cycle on both on pressure entropy, sorry, this pressure volume and temperature entropy diagram.

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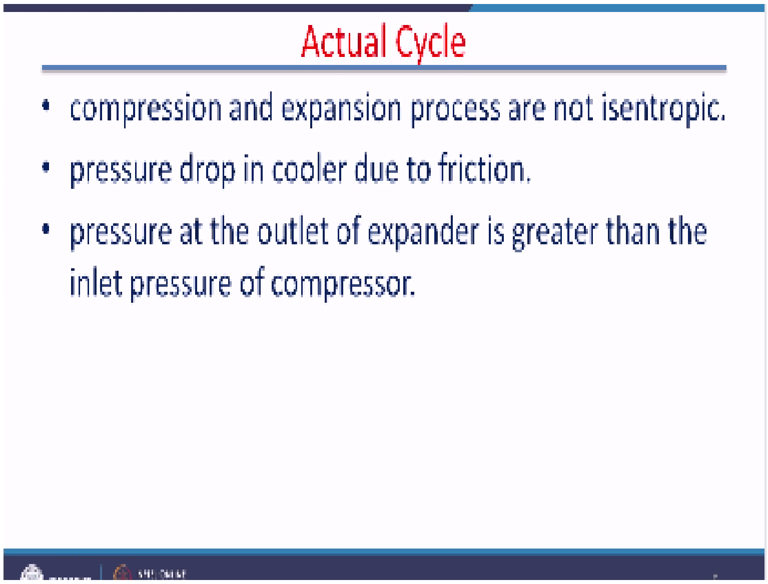

In the actual cycle, first of all, this is a ideal cycle, 1, 2, 3, 4, pressure and volume. In actual cycle, this is no longer a radiometric process, the process will be something like this, it can be shown here a change in the entropy as there is increase in this process, so it is 2 dash. For cooling also temperature may not remain constant, okay. So temperature, sorry for cooling the pressure may not remain constant, the pressure will fall during the process.

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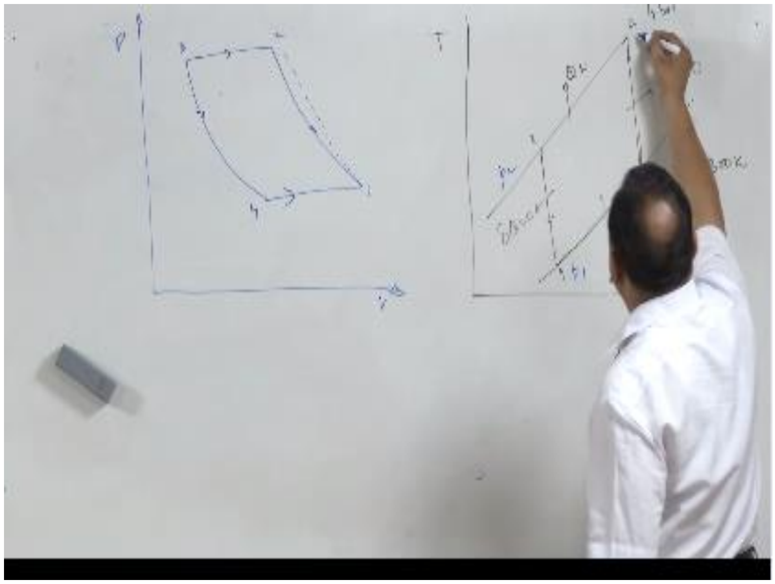

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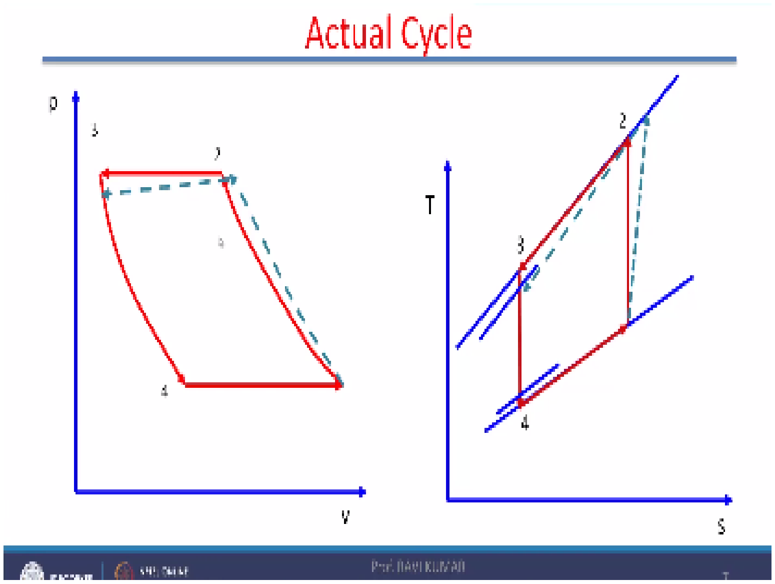

After that expansion also is not an isentropic process, it is again, there is a change in isentropic, so the expansion something like this 12 dash, 3 dash and 4 dash and there is going to be pressure drop in the evaporator or during the heat expansion from the surroundings also. This is actual cycle, so the pressure at the outside of the expander is greater than the pressure of the inner of the compressor. Now with this I end this lecture, In the next class we will take p aircraft refrigeration system.

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