INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NPTEL
NPTEL ONLINE CERTIFICATION COURSE

Refrigeration and Air-conditioning

Lecture-06
Aircraft refrigeration cycles-3

with
Prof. Ravi Kumar
Department of Mechanical and Industrial Engineering
Indian Initiation of technology, Rookee

Hello I welcome you all in this course, on refrigeration and air conditioning, today we will be discussing the aircraft refrigeration cycles, and this is the concluding lecture on aircraft Reformation cycles. so in this lecture we will try to solve one numerical, in engineering courses we solve numerical, or we give new miracles to the students not to judge their computational risk.

In here new miracles are solved, just to have insight of the phenomena because in do miracles you get certain values, and these values give you insight of the phenomena, I have taken data for a aero plane, which is moving with.

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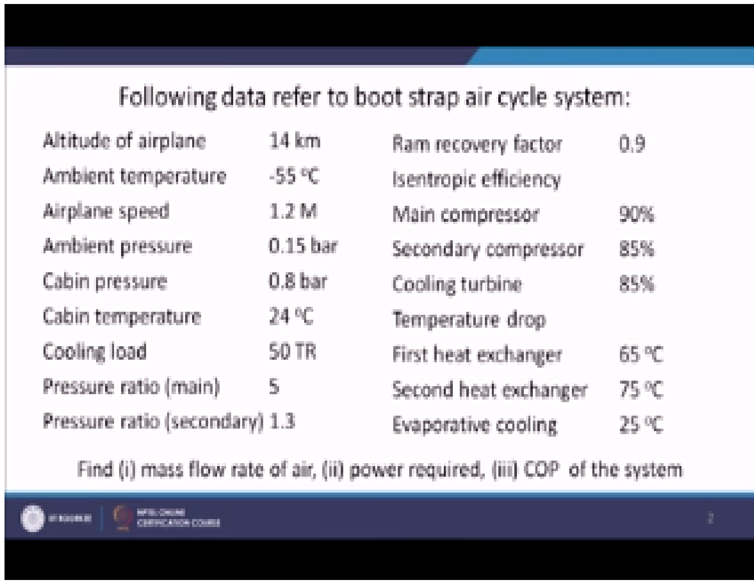

1.2 m velocity, which is supersonic velocity, the aircraft is moving at an altitude of 14 kilometer outside temperature is - 55 degree centigrade. So the aircraft is above the troposphere so temperature is slightly lower it is - 55 degree centigrade, ambient pressure is point 15 bar, so very low cabin pressure has to be maintained point 8 bar, please remember that in aircrafts the pressure is not maintained at 1 bar, 1 bar is ideal but normally the cabin pressure here is taken as 0.8 bar, the ideal pressure would have been 1bar.

But in aircrafts we don’t take one bar normally, the pressure inside the cabin is capped approximately 0.8 bar in order to save the energy, cable temperature is taken as 24^0C, that is ideal comfort temperature, cooling load in the aircrafts 50 TR of refrigeration, pressure ratio in mean compressor there are, two compressors because is a bootstrap type of system.

So the pressure ratio in the main compressor is 5, and pressure ratio in secondary compressor I mean the gas will again, after compression in the main compressor it will get good and again it will get compressed the pressure ratio is 1.3, REM recovery factor, I discussed this well when I will solve the numerical is 0.9, isentropic efficiencies of main compressor isentropic efficiency is 90%, secondary compressor 85% ,cooling turbine 85%, percent and temperature drop-in first feast exchanger it means after first compression, in Main compressor the temperature drop is 65 ^{0}C.

In second heat exchanger the temperature drop is 75 ^{0}C, and evaporative cooling also contribute in temperature drop of 25 ^{0}C, and evaporative cooling is done after the temperature drop in second heat exchanger. Now if we draw temperature entropy diagram for the entire process, bootstrap with evaporative cooling this is entropy and this is temperature.

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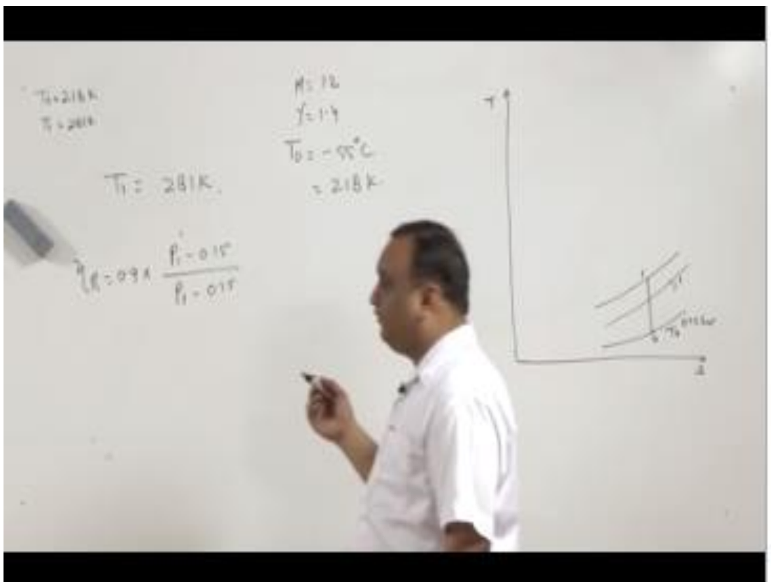

The aircraft is moving with 1.2 m or, air is coming towards the aircraft with 1.2 m, at temperature 0.15 bar, that is to you I will keep on writing values on this side, so that whenever we have to call the values we can call from here, now this is the state 0, now from the state 0 to state 1 the compression takes place, and in order to find temperature at state 1,we will use the equation$T1 / T0 = 1 + \gamma - 1 / 2 m^2$, here the value of m is 1.2 and γ =1.4.

P0 is, will right here P0 so T0 / T1/TO, so TO is this is ambient temperature it is - 55 ^{0}C, this has to be converted into Kelvin, so it will be, 218 Kelvin, now TU is 218 Kelvin, from this equation we can find the value of T1 as 281 Kelvin. So here we will write T_O = 2 18 K,T1 =

281K, so the value of t1 is 281 K, but in this system there is a ran recovery factor, due to ram recovery factor it is 0.9 the pressure will not be attained as one, it will be we'll get some state like a dash, the temperature of a dash equal to temperature of one, but the pressure of a dash is not pressure of one.

It is less then pressure of one, and this a dash pressure can be calculated by using the formula, recovery efficiency = 0.9 x P1 dash, - 0.15/ p 1 / p 1 - 0.15. But we do not have the value of P1, in order to find the value of P1 we will have to go for ideal.

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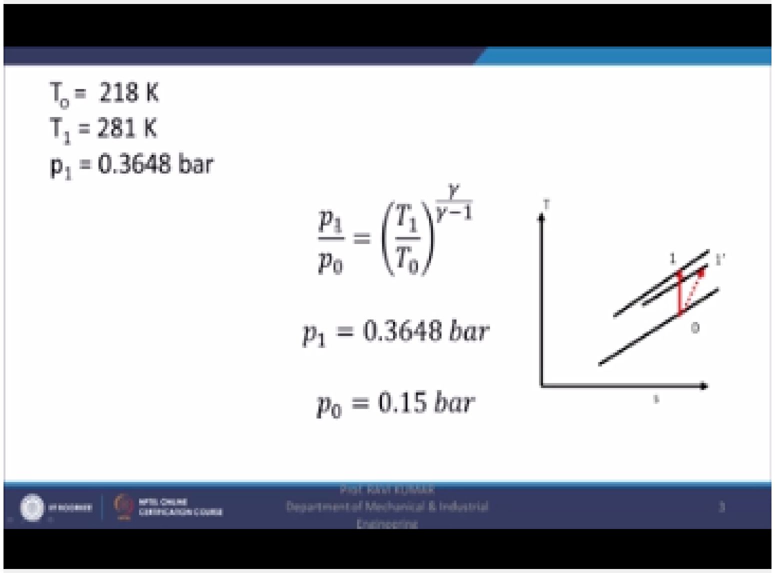

Gas relation that is P1 / P0 = (T1 / TO) $^{\gamma / \gamma\text{-}1}$, by this word that will give the value of P1=0.36 48 bar, PO = 0.15 bar, this is 0.15 bar T 1 and T 0 are with us, and with all these values will be getting the value of P this will know on the p1 also here somewhere here, so later on we can recall, so P1 =0.3 648 bar, now after grading the value of P1.

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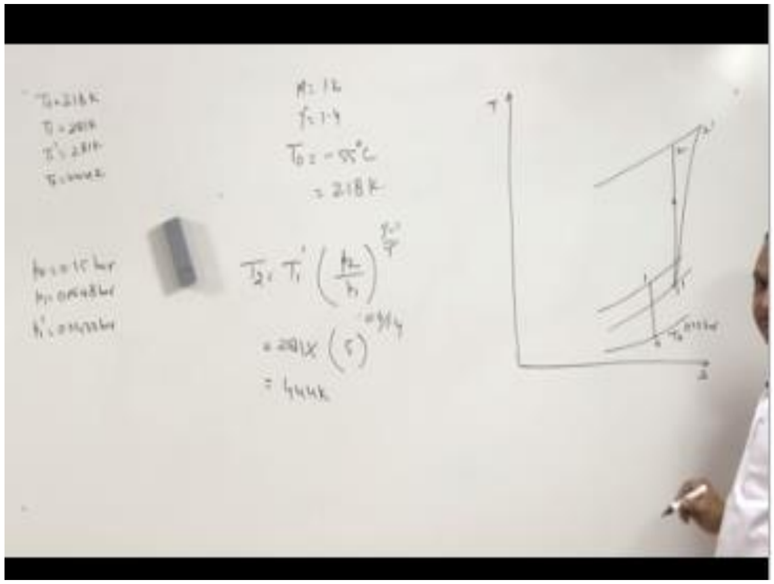

We can easily find the value of T 1 `, because the RAM recovery factor is 0 .9, so 0.9 = p 1` - PO / P1 – P0, now we have the value of P1, what we have the value of PO =0.15 bar, this will give you this will give us the value of P1` and this value of P1` = 0.34 33 bar it is less than P 1, so P 1 is 0.34 33 bar.

Now after finding out the value of P1` now compression will take place, now compression will start from P1`, process 1 to 2, now during this compression the compression ratio is given 5 so T2 is = (T1`P2 / P1), $^{\gamma - 1 r \gamma}$, $\gamma$ value is already with us P2/ P 1 = 5 if $\gamma$ – 0. 4 / 1.4, but T1` and T1 are same, so T 1 ` can always be taken as to it once, so T 1 ` we can write here also 281 Kelvin.
So here 281K ×2 81 and we get the value of T 2 as 444K, now T2=444 Kelvin, as you know this process is not reversible process okay, it has certain isentropic efficiency so instead of getting state 2, we get state 2`, Again we will use polytrophic efficiency equation here, and try to find the value of T2` so Polly traffic efficiency equation here.

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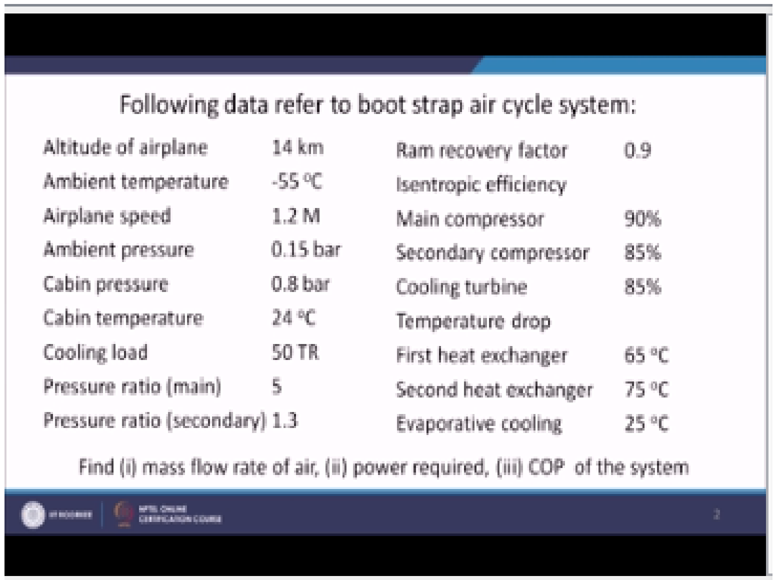

Is polytrophic efficiency of compressor been, compressor main compressor polytrophic efficiency.

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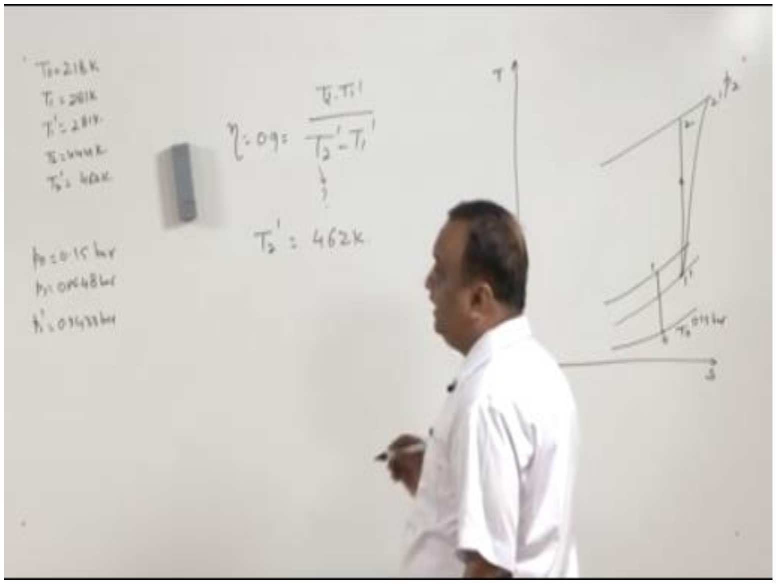

Is 0.9 = T2-T1` / T2` - T1`, T2` is not told to us it is not known to us T2 is 444 KP1´ is 281 K using these values we can find the value of T2´and T2´ is 462 K so now we have another temperature at this pressure T2 is T2´it is equal to 462 K after this the air emerging from compressor is sent to the heat exchanger.

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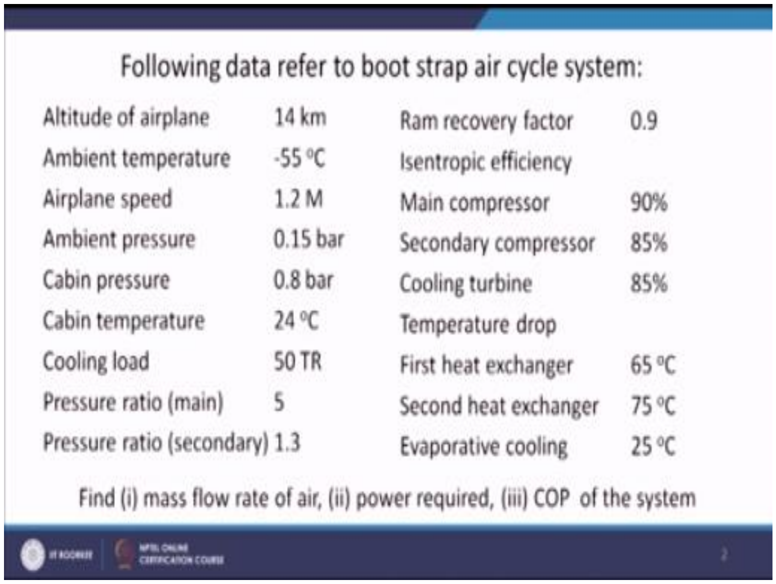

And in the first heat exchanger the temperature drop is 65 degree centigrade.

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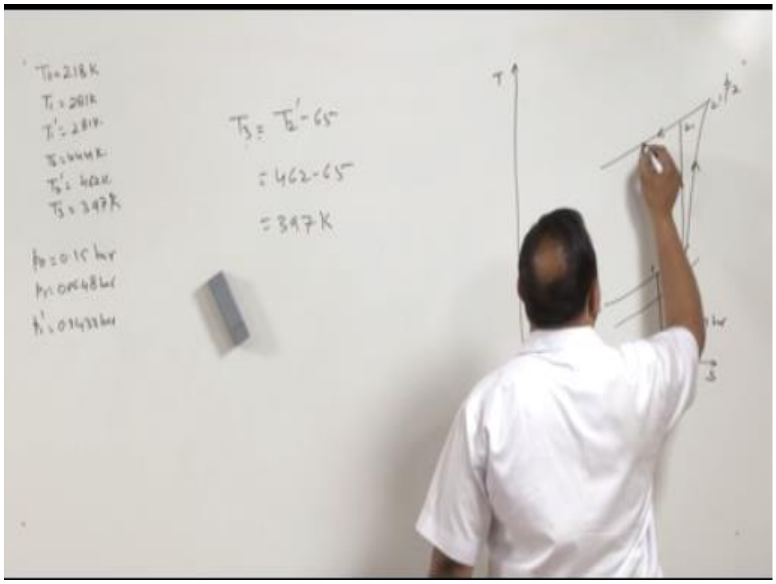

So T3 is equal to T2´ - 65 or 462 – 65 or 397 degree centigrade so free will comes up were here so this process and then this process 3 so T3 is 397 degrees sorry it is K not degree centigrade k with because temperature drop is 65 degree centigrade because there is a change in temperature that is why we did not convert into the K so the T3 temperature at state is 397 K.

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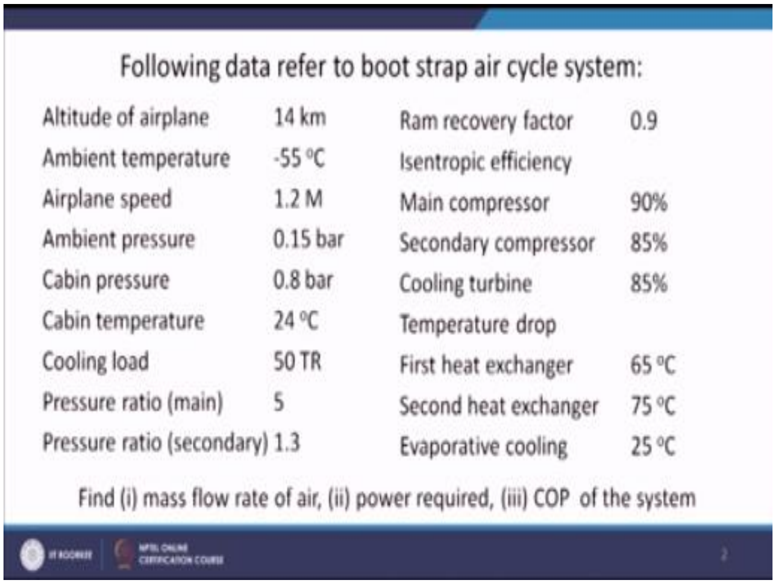

Now again compression takes place in second compressor and second compressor has efficiency of 85%.

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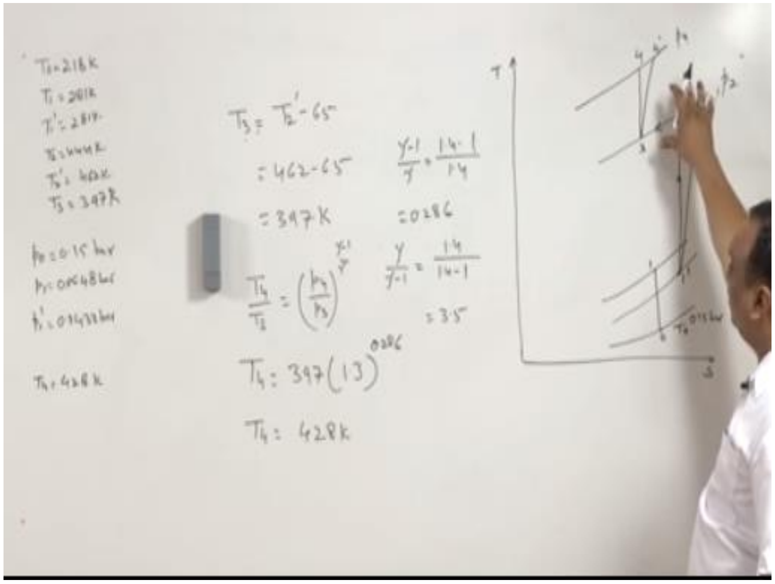

4 and again it is 4' this is second compressor this is let us say T4 so in both the states the pressure is seen but the temperature is different so in order to find the temperature in the state 4 T4/T3 is equal to P4/P 3 raise to power γ-1 over γ now T4/T3 as it is given in the numerical value itself it is a pressure ratio 1.3 so T4 is going to be equal to T3 you can take from here 397 into 1.3 raised to power this γ-1 by γ is equal to 1.4 -0.4 /1.4 and it turns out to 0.28 6and γ over γ-1 is 1.4/ 1. 4- 1.4minus 1.

Here it is not 1 is 1 so 1.4 minus 1it turns out to be 3.5 so next I will take directly values from here 0.286 3.5 so here it is 0.286 and the value of T4 we are getting here is 428 k so we will write somewhere here T4 we will write here P4 is 428k but this process is also not reversible process so instead of having the state here we will get state T4' and as we did in the case of the main compressor here also we will use the same formula using the efficiency of the compressor

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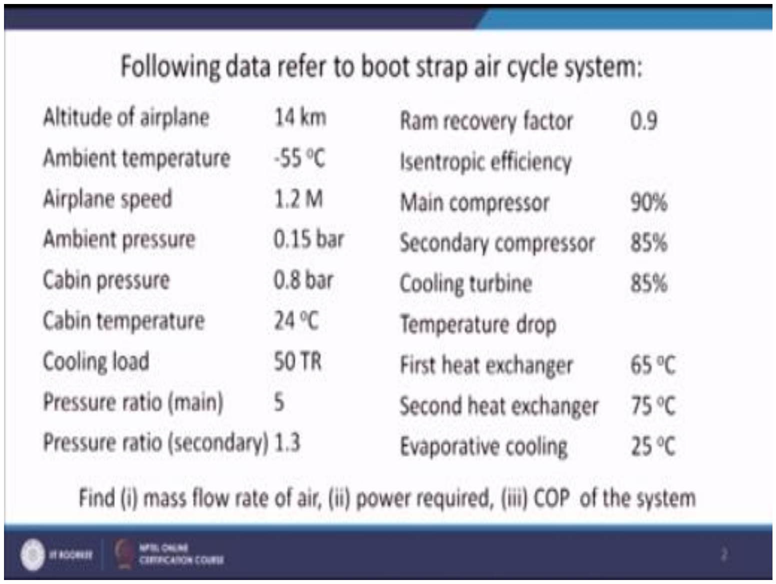

That is in the efficiency of the second compressor is 85%.

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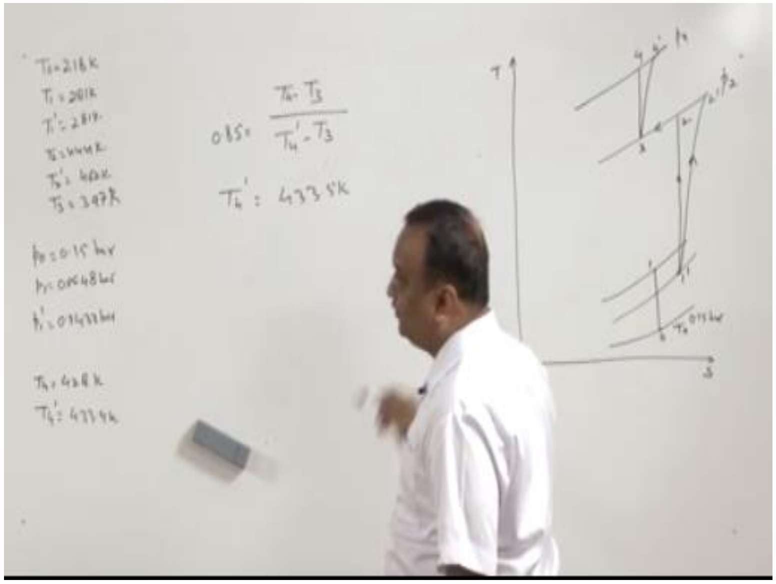

So 0.85 = T4 - T3/ T4'- T3 now T4 and T3 we can take from here and this will give us the value of T4' S 4 33.5 k so We can write here T4' is for 33.5k after it a big state 4' the gases or the air is further cool and in secondary is actually exchanger the cooling is by 75 degree centigrade so it is cooled up to 75 degree centigrade here.

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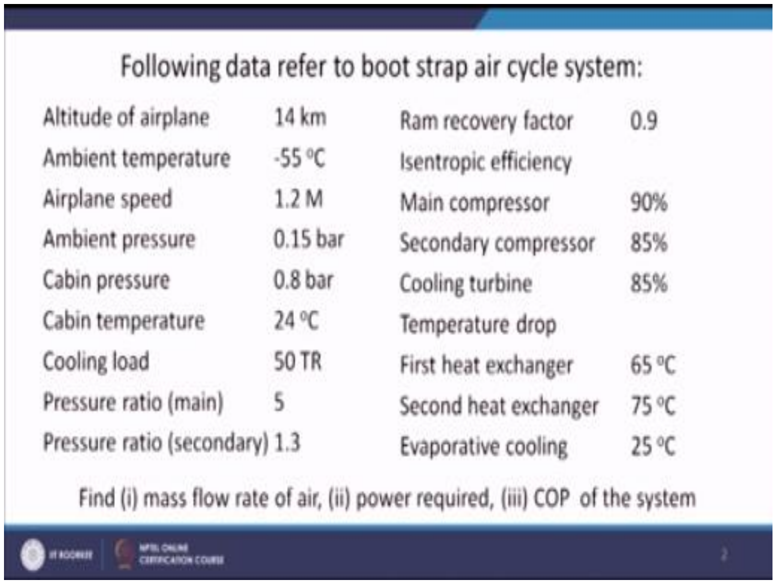

Now again it is further cooled by evaporative cooling so 75+ 25 so total is 125 this is 25 degree.

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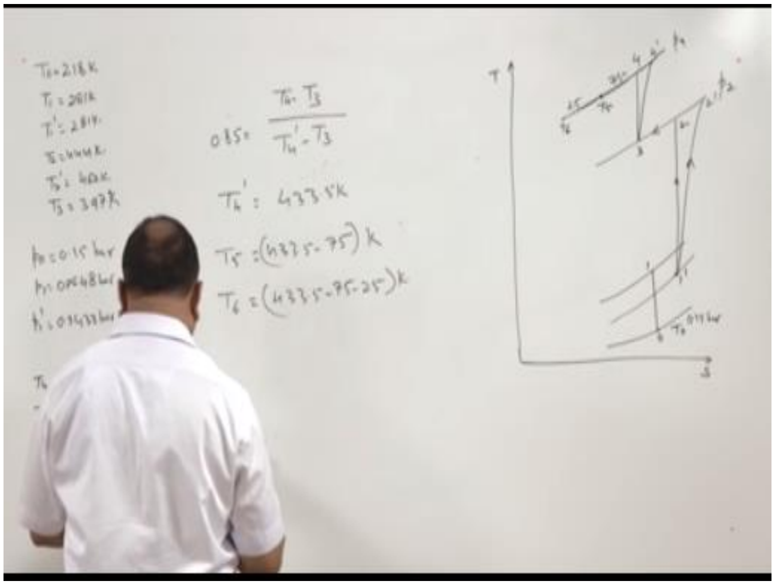

And this is 75 degree so one is total is 125 degree so if we remove or if you suspect 433-125 so T5 now we can write here T6 this is T5 and this is T6 so T5 is 433.5 -5 k and T6 is 45 -75 - 25 k and that is why we get T6S.

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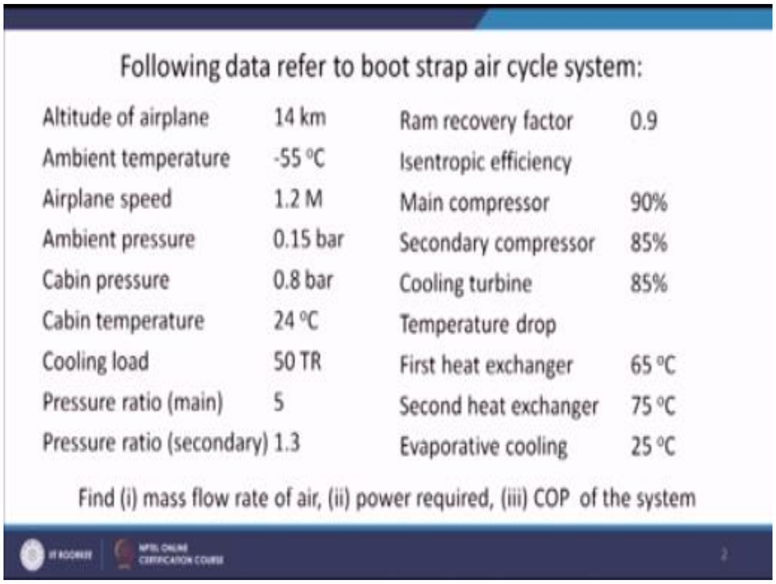

Yes there is a correction here that you have read new cooling is not 25 degree centigrade we will take it as 50 degree centigrade so I will make necessary Corrections here so here I have modified the value of your bloody cooling it is 50 degree centigrade earlier it was 25 degree centigrade now I have modified it to 50 degree centigrade so if it is 50 degree centigrade then T6 we are going to get it is 50 degree centigrade 50.

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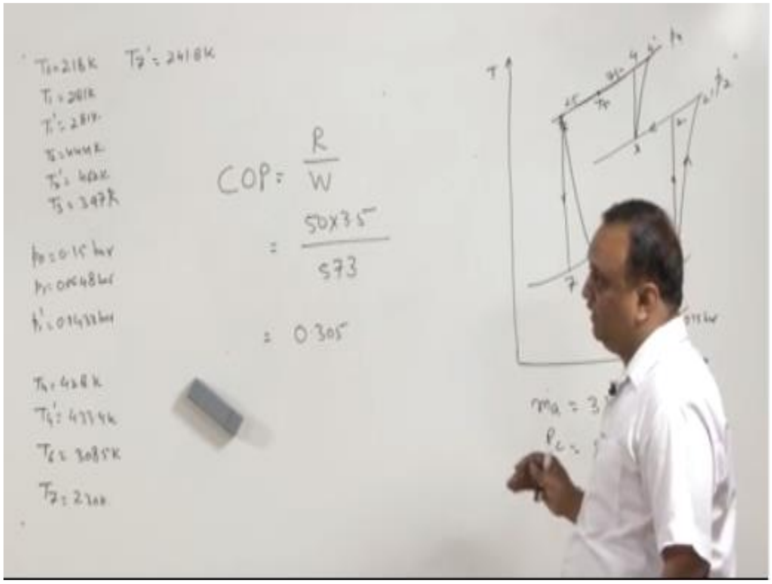

So T6 we are going to get 308.5 K so now T6 T6 T4 T5 T6 = 308.5 K now air available here shall expand but pressure we do not know right now we know the pressure ratio pressure ratio between this and this pressure ratio between this and this but absolute pressure at this 0.6 is not known to us so in order to find this pressure at 6 P6 is the pressure at state 1' pressure at state 1' that is 0.3433 x pressure ratio 1' to 2 5x 1.3 and that is going to be equal to 2.23 bar now we have pressure at this state and temperature at this is state expansion will take place and it will be expanded up to 0.8 bar the cable pressure is 0.8 bar .

So it is higher than the 0.1 so 0.8 bar will come somewhere here 0.8 bar so the expansion will takes place from 2.23 bar 2.8 bar still the expansion turbine has certain efficiency that is 85% so again we will get 7 and 7' so T7 / T6 = T7/ T6 raise to power again γ- over γ and from here we will get the value of T7S 230 k so T7 is 230 k again this process is not ideal process so instead of getting state a seven we will be getting state 7'

And now again we will consider the efficiency of the expansion turbine that is cooling turbine that is 85= T7' – T6/ T7 – 76 we have the values of T7 we have the values of T6 this will give us the value of T7'S 241.8 k so T7' is 240 1.8 K now we have the temperature of air which is used for the cooling purpose and temporal inside temperature is maintained at 24 degree centigrade so 24 degree centigrade will turn out to be 24 + 273 = 297 Kelvin now we have to find mass flow rate of air.

So mass flow rate of air mass flow rate of the air will be can be taken as or can be calculated by just dividing the total cooling capacity that is 50 ton x 3.5 kilowatt that is total cooling capacity / cooling by 1kg of here that is CP(T) sorry CP 297 – T7' is 41.8 this is the total cooling capacity of the refrigeration system and total cooling capacity is given in terms of refrigeration that is why it is x 3.5 to convert it to the kilowatt of cooling divided by the cooling by 1kg of air and the CP can also be replaced by 1.0005 and this will give us the mass flow rate in kg per centimeter per second that is 3.15 kg per second so that is one answer we are getting here that mass flow rate or this ma . ma. is 3.15 kg per second power required by the compressor.

So power required by the compressor is mass flow rate of air x CP T2' – T1CPDT we have already done that the power consumed where the compressor can be expressed by CPDT CP T2 – T1 here it is T2' – T1' and T2 and T1'can be taken from here and CP value is known to us ma is known to us this gives the power of the compressor is 573 kilowatt so power consumed by the compressor is 573 kilowatt now the third one is COP of the system coefficient of performance of the system.

So coefficient of performance is a refrigerating effect / the work consumed by the compressor so refrigerating effect is 50X 3.5 kilowatt / 573 that is the power consumed by the compressor and this will give us the COP of the system is 0.305 so COP of the system is 0.305 so you have got all the answers and perhaps the solution of this problem must have given you the clear inside of the phenomena and now we have numbers approximate numbers at each stage now in subsequent lecture we will start with the vapor compression system vapor compression refrigeration system in vapor compression refrigeration system the heat addition and heat rejection takes place at constant temperature or during phase change of the working fluid.

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For Further Details Contact

Coordinator, Educational Technology Cell
Indian Institute of Technology Roorkee
Roorkee – 247667
E Mail: etcell@iitr.ernet.in, etcell.iitrke@gmail.com
Website: www.nptel.ac.in

Acknowledgement
Prof.Pradipt Banerji
Director, IIT Roorkee

Subject Expert & Script
Prof.Ravi Kumar
Dept of Mechanical and
Industrial Engineering
IIT Roorkee

Production Team
Neetesh Kumar
Jitender Kumar
Sourav

Camera
Sarath Koovery

Online Editing

Jithin.k

Video Editing

Pankaj Saini

Graphics

Binoy.V.P

NPTEL Coordinator

Prof.B.K.Gandhi

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