Concepts of Thermodynamics
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Lecture – 26
First Law for SSSF Process: Example Problem (Contd.)

We have been discussing about problems related to the First Law of Thermodynamics for steady state, steady flow process and we will continue with the problem solving in this particular lecture. So, the first problem that we will consider in this lecture is problem 4.6.

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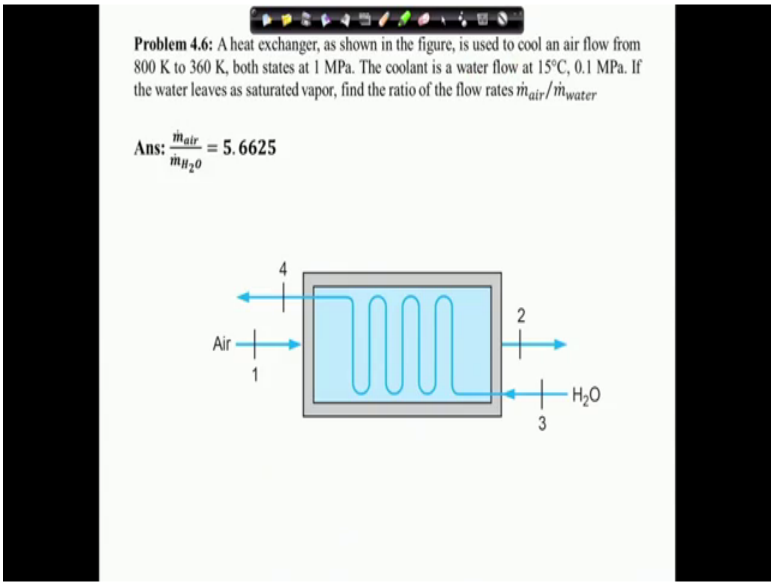

A heat exchanger as shown in the figure is used to cool an air from 800 Kelvin to 350 Kelvin, both states at 1 mega Pascal. The coolant is a water flow at 15 degree centigrade 0.1 mega Pascal. If the water leaves at saturated vapor, find the ratio of the mass flow rates? So, let us draw the schematic in the board and then we will solve the problem. This problem is very similar to the condenser problem that we solved.

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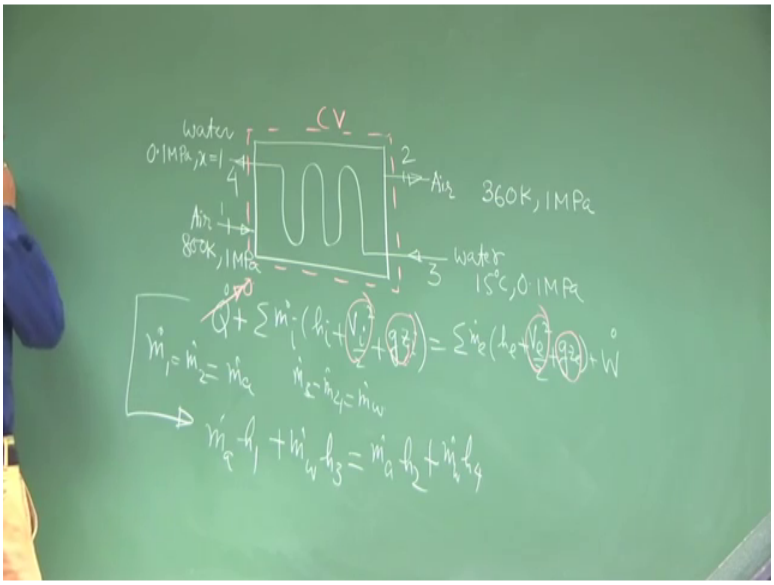

So, we will not take much time for it. So, as we discussed earlier, the purpose of the heat exchanger is to exchange the heat between the two streams, here the streams are air and water. So, we will construct a control volume. So, straight away, there is no external heat transfer. Kinetic energy and potential energy changes are neglected and m dot 1 is equal to m dot 2, right, this is air state 1, this is state 2.

So, m dot 1 is equal to m dot 2 is equal to m dot air and m dot c is equal to m dot 4 is equal to m dot 1. So, from this equation, you can write m dot air into h 1 plus m dot water into h 3 is equal to m dot air into h 2 plus m dot water into h 4 ok. So, what is asked is, what is the ratio of m dot air by m dot water?

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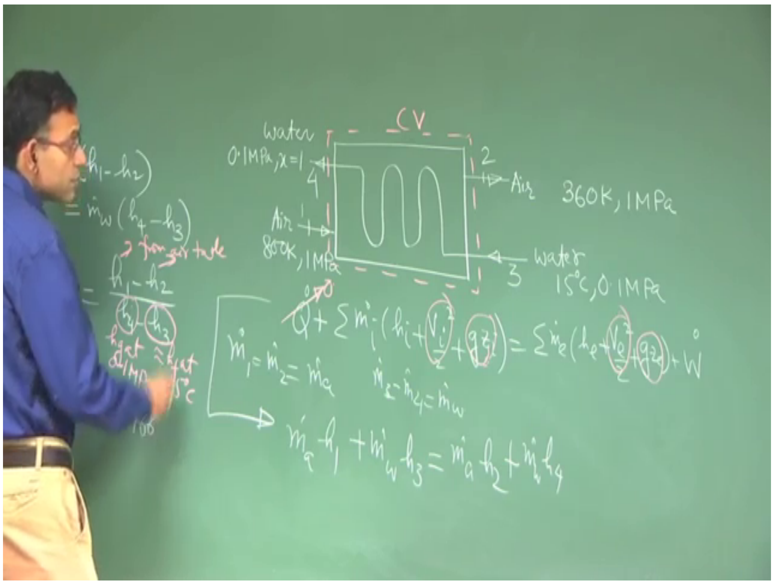

So, m dot air into h 1 minus h 2 m dot water into, so what is asked is m dot water by m dot air. So now, h 1 minus h 2; so, these values, see these are air with a widely varying range of temperature. So, it is better to use the air table instead of considering constant CPCB. So, in any in the appendix of any book of thermodynamics, you will find that in the property tables, you also have properties of air.

And there, it is assumed that air is ideal gas, but CPCB may not be constant. So, then you can get h 1 minus h 2. So, h 1 and h 2 both from air table, h 3 is water at 15 degree centigrade with 0.1 M Pa. This you can approximate as h f at 15 degree centigrade, this is compress liquid, but it is enthalpy can be approximated as saturated liquid. And h 4 is h g at 0.1 M Pa. So, if you calculate all these, the ratio will be 0.1766 ok.

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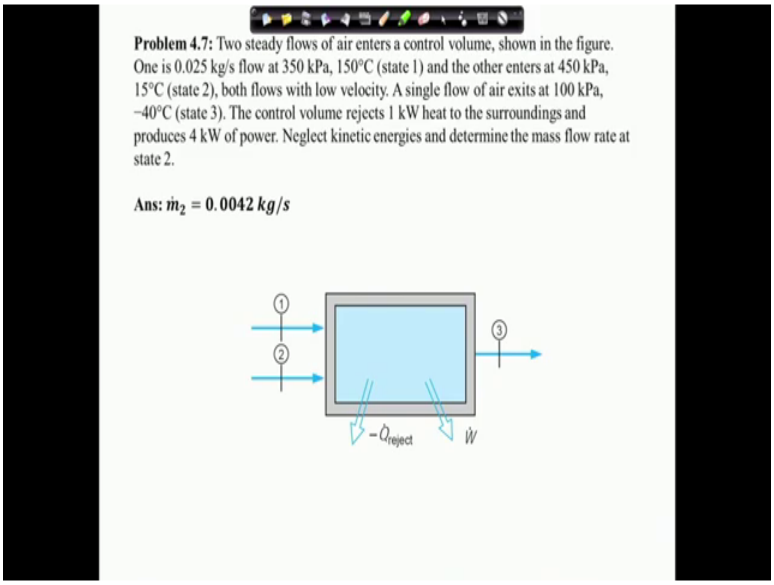

We will consider the next problem, problem 4.7. In this problem, you see two steady flows of air enter a control volume as shown in the figure. One is 0.025 kg per second at 350 kPa, 150 degree centigrade; this is state 1. And the other is 450 kPa, 15 degree centigrade, state 2. Both with low velocity; that means, you can neglect the kinetic energy of the inlet states.

A single flow of air exists at 100 kPa minus 40 degree centigrade, state 3. A control volume rejects 1 kilo Watt heat to the surroundings and produces 4 kilo Watt of power. Neglect kinetic energy basically, neglect changes in kinetic energy, that should be a better way of you know stating this determine the mass flow rate at state 2 ok. So, let us workout this problem. Let me as our standard practice draw a schematic of this.

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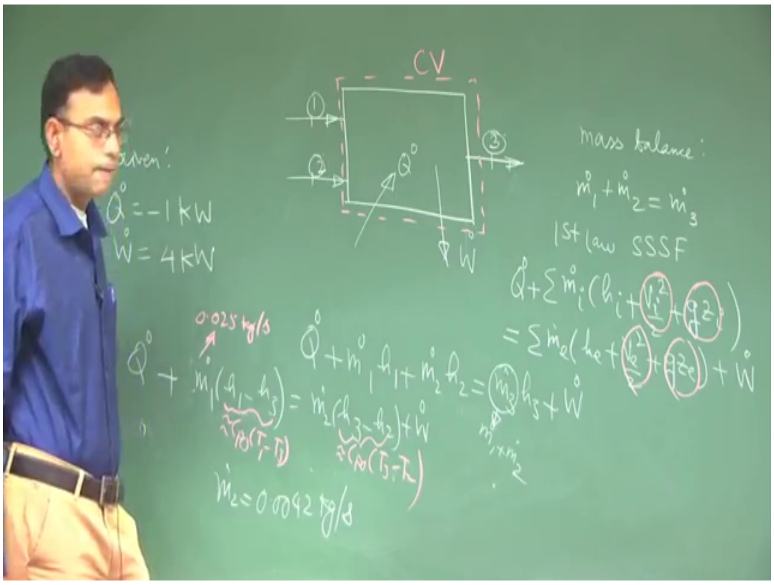

So, for solving problems, I always prefer that we show positive direction of heat transfer and positive direction of work done as we have used for the derivation. If instead of heat addition it is rejection, it will be negative. So, that because if we show the direction itself as opposite, then sometimes you know there is there can be an algebraic confusion in writing the energy equation.

So, for this control volume, let us write mass balance and energy balance; energy balance. 1st law let us see what is given one by one. So, it is given that first of all, you can neglect changes in kinetic energy and potential energy. So, these changes you can neglect. So, you can write Q dot and m dot 3 you can write m dot 1 plus m dot 2. So, Q dot is given, Q dot is now let us write the given data here; W dot is 4 kilo Watt. So, now, you can write Q dot. So, let us see what is given state. So, m dot 1 is, so let me write it a different color.

M dot 1 is 0.05 kg per second, m dot 2 is not known and all the fluids are air essentially. Let us look into the temperature range, minus 40, 50, 150. So, temperature range is there, it is not as large as say 500, 600, 700 like that, but temperature range is there.

So, I would as you to solve the problem in two ways; one is, find out this property differences from air table approach 1; find out these property differences by assuming this as this. So, you do it in this way and substitute the value of heat and work, you will get m dot 2 is this. So, you can try with looking into the air table without using this approximation and see what mass flow rate. You will get in this problem, you will get a value very close to it ok.

So, we will work out another problem. So, that problem is, problem next problem, problem 4.8.

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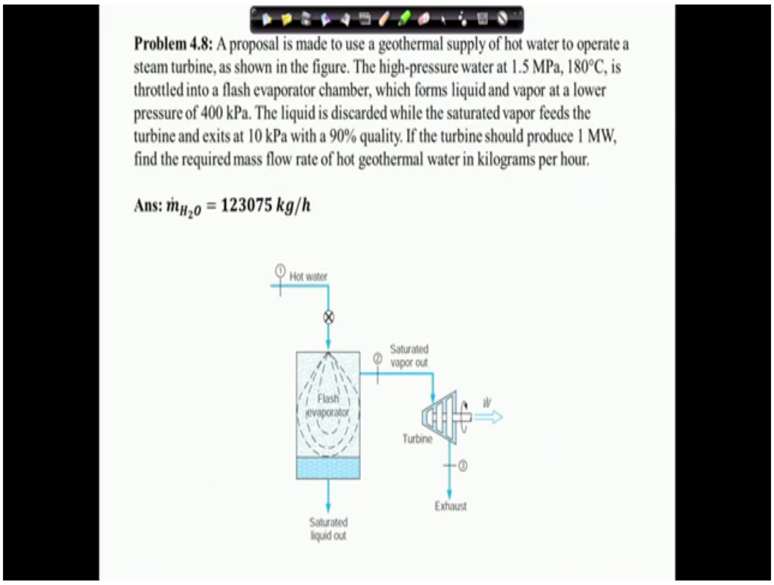

So, a proposal is made to use a geothermal supply of hot water to operate a steam turbine. So, steam turbine requires high enthalpy fluid, right. So, there is a geothermal supply of hot water, it is used to operate a steam turbine. The high pressure water at 1.5 in Pa, 180 degree centigrade that is corresponding to state 1, here it is throttled into a flash evaporated chamber which forms liquid and vapor at a lower pressure of 400 k Pa.

The liquid is discarded that is the saturated liquid comes out of the evaporator and the saturated vapor feeds the turbine and exits at 10 k Pa with 90 percent quality. The turbine should produce 1 mega Watt. Find the required mass flow rate of hot geothermal water in kg per hour ok.

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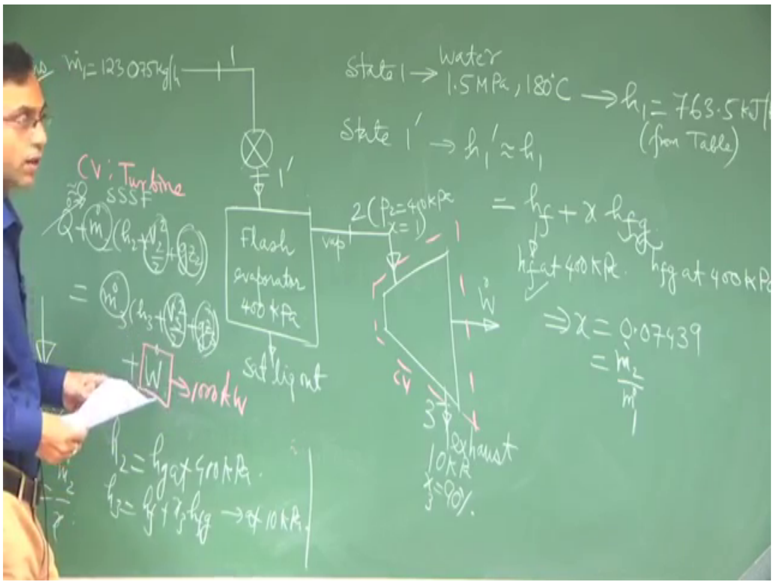

So, let us draw the schematic. This is typically the symbol of a throttle valve this cross. So, let us write the values here, state 1. State 1 is water 1.5 m Pa, 180 degree centigrade. State 1 prime, what is it? So, we have learned the throttling process, state 1 prime across the throttle valve you have negligible change in enthalpy. So, h 1 prime is equal to h 1. So, then this entire process it is this is throttled to 400 kilo Pascal right. So, water at 1.5 m Pa, 180 degree centigrade, it will have h 1 is equal to 763.5 kilojoule per Kelvin from table.

So, this you can write, this is reaches at 400 kilo Pascal, the pressure at which the flash evaporator operates. And this is h f g at 400 kilo Pascal. So, you know h 1, so, from here, you can find out what is x. So, x you will get 0.07439 this is the quality. See, what is the definition of quality, it is the mass of vapor by total mass and out of these steam vapor mass is coming out here and liquid mass is coming out here. So, this is nothing but m dot 2 by m dot 1 ok.

So, this is the very important step. So, it is not just a formula but you have to understand the physical meaning of the definition of quality, mass of vapor by total mass and here only the vapor is coming out. Then, you can consider the control volume as the turbine. The steady state, steady flow process, we neglect heat transfer across the turbine, we neglect changes in kinetic and potential energy and m dot 2 and m dot 3 are the same and the turbine produces 1 mega Watt. So, this is now 1000 kilo Watt. Normally, we use kilo units for substituting all the values because enthalpy values are in kilojoule per kg as you get from the table. So, that is why I had put it in kilowatt. So, from this equation, h 2 is you already know what is h 2. So, what is h 2? This is the state 2 is given. State 2 is 400 kilo Pascal and quality equal to 100 percent.

And state 3 is 10 kilo Pascal, quality equal to 90 percent. So, you can calculate what is h 2 is equal to h g at 400 kilopascal and h 3 is equal to h f plus h 3 h f g at 10 k Pa, if x is equal to 0.9.

So, you can get an m dot 2 and m dot 3 are the same. So, from this equation, my substituting the values you will get what is m dot 2? The answer required is what is m dot 1? So, from this equation, m dot 1 is m dot 2 by x, this x not this x, this is x 3.

So, this if you convert it into kg per hour unit. So, it will come out as kg per second. So, if you convert it into kg per hour unit, then answer is m dot 1 is equal to 123.075 kg per hour

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123.075; 123.075 ok. So, let us stop here today, we have solved a few problems related to the steady state steady flow energy equation. There are many situations when the process in the control volume is such that the steadiness of the process is not maintained and it is an unsteady process by it is intrinsic nature.

In the next lecture, we will try to see that if it is an unsteady flow problem, then how to do a control volume analysis.

Thank you very much.