Concepts of Thermodynamics
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Lecture - 25
First Law For SSSF Process: Example Problem (Contd.)

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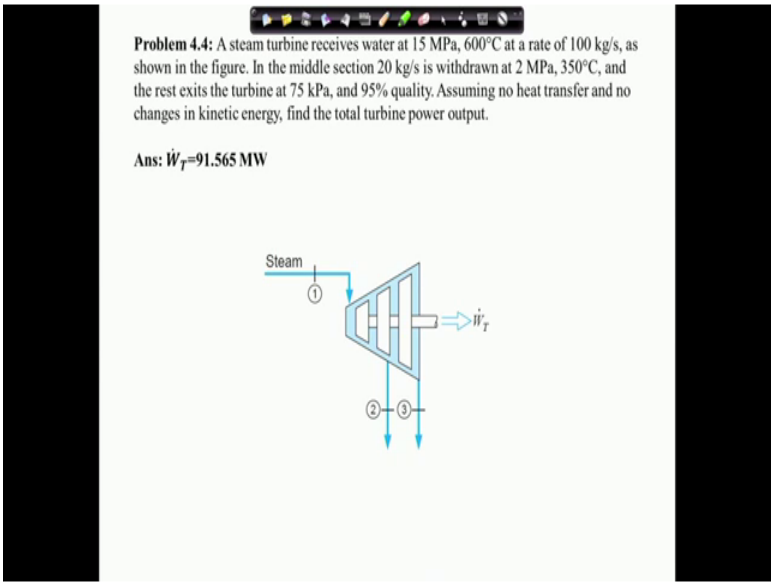

We have been working out some problems on the Steady State Steady Flow energy equation and we will continue with the problem solving in today's lecture. Let us look into the slide to first look into the problem statement of problem 4.4. A steam turbine receives water at 15 MPa 600 degree centigrade at a rate of 100 kg per second. In the middle section 20 kg per second is withdrawn at 2 MPa 350 degree centigrade and the rest exists the turbine at 75 k P a 95 percent quality. Assuming no heat transfer and no changes in kinetic energy find the total turbine power output.

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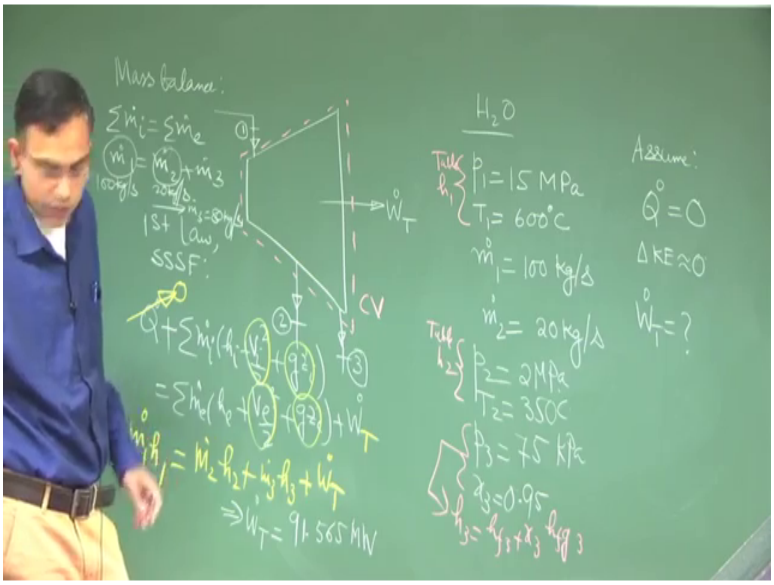

So, let us go to the board to make a schematic. So, to explain what is a steam turbine you have steam entering from a nozzle with a high kinetic energy into the turbine and it hits the turbine blades. There is a change of rate of change of moment of momentum or angular momentum that gives a net torque with respect to the axis of the turbine shaft and the turbine shaft starts rotating. So, that is how from steam power is generated.

So first steam with high thermal energy enters the nozzle, the nozzle converts the thermal energy to kinetic energy and then with a very high kinetic energy the steam falls on the blades of the turbine and the blades start rotating like this. So, now so turbine is a work producing device that is for sure, so in this case let us note down the properties, so the fluid is water.

So, assume and change in kinetic energy equal to 0, change in potential energy we neglect almost for all problems of these types. So, you have to find out the total turbine power output. There are such problems where changes in potential energy are important, for example had it been a water turbine where the water is falling from a high altitude and falling on the blades of coming to the, falling on the turbine blades in those cases turbine blades are not really called as blades, but I mean they are equivalent to the blades of the steam turbine.

So, if water is falling from a very high height to a low height, then obviously, the change in potential energy is important. In this case it is not the gravitational energy heat converted into power, but the thermal energy converted into power and that is why the potential energy change is neglected. So, now this is our control volume, we will apply the first law.

So, here the trick of solving the problem is there are multiple inlets and multiple in this case 1 inlet but multiple exists, so you have to use this. So, here the heat transfer is neglected, change in kinetic energy and potential energy are not important and this is the turbine power. So, inlet is 1, so you have m dot 1 h 1 exit is 2 and 3.

Now problem is very straight forward so if you know p 1 and T 1 from the table, steam table you know what is h 1 p 2 T 2 from steam table you know what is h 2 p 3 you know and quality you know, so from the table you have.

So, if you substitute all these values you will get w dot T m dot has to be walked out right, you have the mass balance at steady flow condition m dot 1, this is 100 kg per second this is 20 kg per second this means n dot 3 is 80 kg per second. So, now you can substitute the values here and you will get what is W dot T, so W dot T. Let me erase the board before we solve the next problem.

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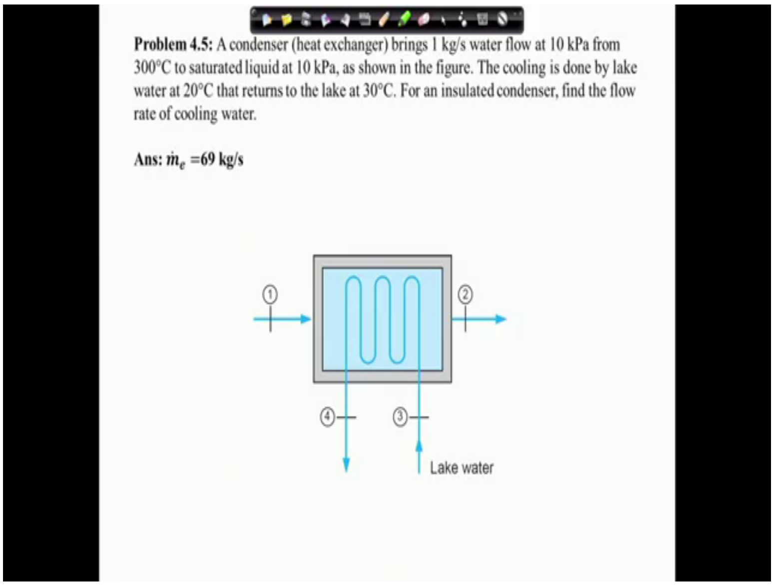

Problem 4.5, so a condenser which is a heat exchanger, so I will explain you what is a heat exchanger and what is a condenser before solving the problem. But let us go through the problem statement first, it brings 1 kg per second water flow at 10 kPa from

300 degree centigrade to saturated liquid at 10kPa as shown in the figure. The cooling is done by lake water at 20 degree centigrade that returns to the lake at 30 degree centigrade. For an insulated condenser find the flow rate of the cooling water.

So, what is the heat exchanger? So, heat exchanger is a device where you can have exchange of thermal energy between 2 fluid streams without requiring the interference of any external heat transfer. So, it is a device where there is a hot fluid which gives it is thermal energy to the cold fluid and in that process the cold fluid gains thermal energy and the hot fluid loses thermal energy. But it is an exchange of thermal energy between these two fluids, so that external heat transfer is not involved. This device also is not required for any work transfer, so it is mainly just the exchange of thermal energy between various fluids streams.

What is the Condenser? So, let us imagine that there is a turbine and steam comes out of the turbine, now that turbine, that steam still is in a state of high thermal energy. So, that has to be converted into a state of low thermal energy we will see later on that this conversion is necessary to maintain the thermal power plant work in a cycle. So, if this heat is not rejected by the steam then in a continuous cycle work cannot be produced by the turbine, this particular principal is governed by the second law of thermodynamics and you will come to that later on.

What is important for this discussion is that in the condenser the steam loses it is thermal energy, so there must be a cold fluid. What is that called fluid? The cold fluid is typically lake water or river water and therefore you will find that mini typical thermal power plants are located in the banks of rivers or lakes like that.

So, it will just take the cooling water from there and then the steam will give it is thermal energy to the cooling water in the process the steam will come to low enthalpy state. So, that kind of device we are talking about here and let me draw a schematic in the board before we solve this problem.

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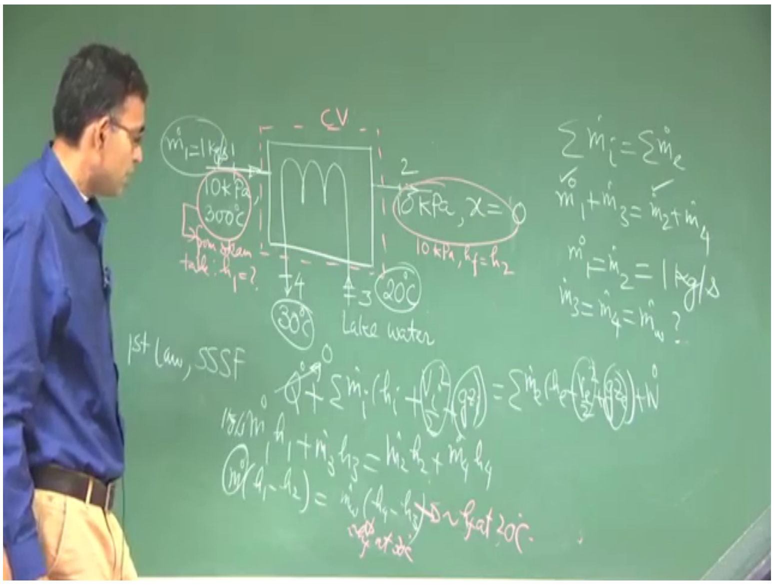

So, this is m dot 1 kg per second, 10 kPa 300 degree centigrade this is actually the exit state of the turbine and then it comes to 10 kPa same pressure and quality equal to 100 percent saturated liquid at 10 kPa sorry, quality equal to 0 saturated liquid right. Then here lake water enters at 20 degree centigrade and by taking heat from the steam the lake water leaves at 30 degree centigrade. The control volume this is the condenser which includes the heat exchange path between the steam and the lake water.

So, before applying the mass balance and energy balance, there is a common sense issue that we need to sort out. See if your solving the problem for the first time and you do not have a clear idea what is happening you can write the mass balance clearly out of these only this is known. So, you might be that you know there are so many unknowns, but from the physical description of the problem this is the steam line. So, what is m dot 1 the same is m dot 2, so m dot 1 is equal to m dot 2 this is 1 kg per second and m dot 3 you do not know what it is that is m dot water but they are equal.

Now you apply the first law steady state steady flow, energy equation for the control volume. So, first of all in the heat exchanger there is exchange of heat between the 2 streams, so there is no external heat transfer. So, by the name heat transfer heat exchanger do not get confused that this is there so this is 0, then you can neglect the changes in kinetic energy and potential energy.

So, you have m dot 1 and m dot 2 are let us say this is m dot both are 1 kg per second so m dot into h 1 minus h 2 ok. So, this is 1 kg per second and then h 1 and h 2, so 10 kPa 300 degree centigrade you get h 1 h 2 is this, how do you estimate h 3 and h 4? See these are essentially liquids at 20 degree centigrade and 30 degree centigrade. So, their properties will be very close to saturated liquid at 20 degree centigrade and 30 degree centigrade. Actually they are in the compressed liquid phase not saturated liquid, but their properties will be very close to the saturated liquid state. So, h 4 will be approximately h f at 30 degree centigrade and h 3 will be approximately h f at 20 degree centigrade.

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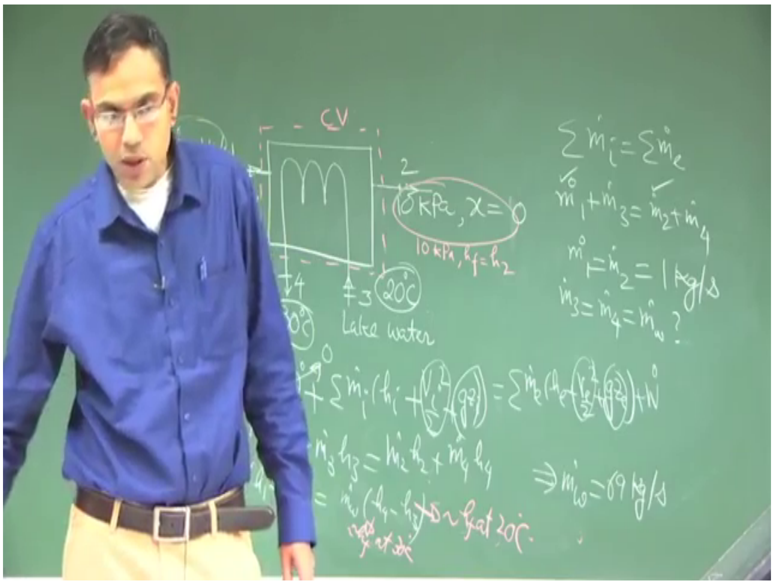

So, if you now calculate all these, you will get m dot water as the only unknown which is 69 kg per second. So, in today's lecture we have discussed about 2 very interesting problems one related to turbine and other related to condenser, these are very important essential components of a thermal power plant. So, we can see through these exercises that by using the simple mass balance and energy balance how can we analyze this devices from fundamental thermodynamics considerations.

Thank you very much we stop here today and we will continue with the next lecture with more problems.