Concepts of Thermodynamics
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Lecture – 27
Supplementary Lecture: Problem Solving with the Aid of a Computer

Hello, everyone and welcome to this session in which we will consider a geothermal supply of heat and how to extract that and we will make yourself a computer to find out the work output and what the mass fluxes we need to have those work outputs.

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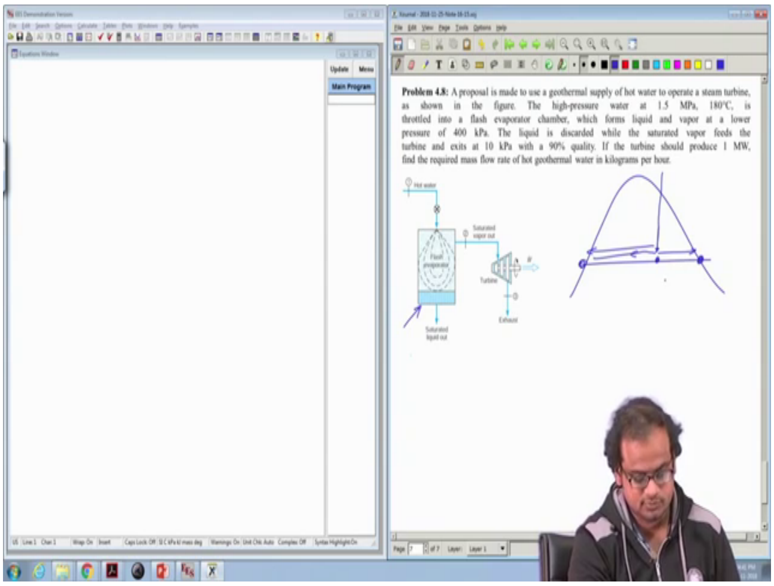

So, what happens is you have hot water; so, the geothermal energy how it is utilized is you have water in the subsurface at a higher temperature and then you extract that water to the surface that hot air is that water is usually hotter and it is at a higher pressure ok. So, that high pressure high temperature water is first flashed. So, the meaning of flashing is its converted into a two-phase zone in which you separate out the liquid and you separate out the vapor. In a two-phase zone inside the two-phase dome, if you are flashing something then you extract the liquid here and you extract the vapor over here. You come at this point and any flash it ok, so, this is called as flashing.

So, you extract the liquid and vapor separately and then the vapor you pass on to a turbine the turbine then rotates and you extract some useful work. So, let us see what we have.

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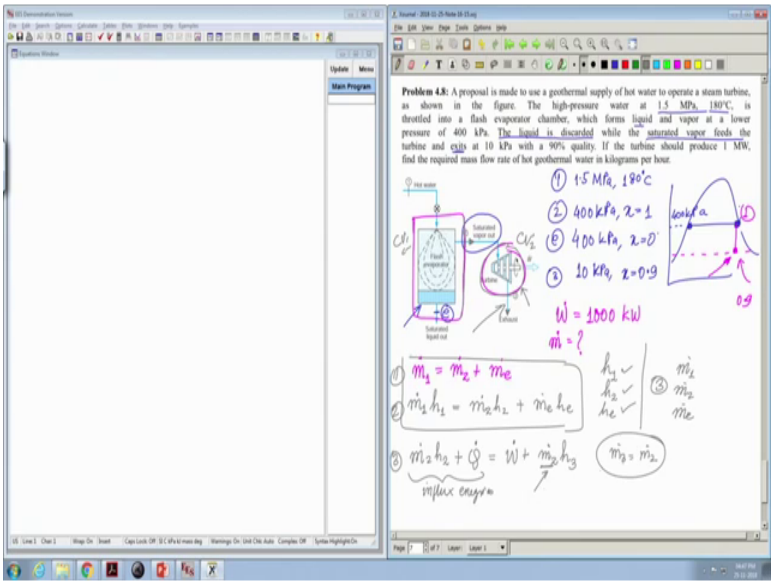

We have high pressure water at 1.5 mega Pascal. So, state 1 1.5 mega Pascal of water and 180 degree Celsius. It is throttled into a flash chamber which forms liquid and vapor at a lower pressure of 400 kilo Pascal. So, state 2, would be at 400 kilo Pascal x equal to 1, because like I showed this vapor output is extracted here. This pressure is 400 kPa, but this is not extracted this is extracted ok, whatever comes here is extracted ok.

So, let us call this as state e. So, that is the exit state. So, exit state is 400 kPa x equal to 0. The liquid is discarded ok, this liquid is discarded while the saturated vapor feeds the turbine and exits, so, the exit of the turbine. So, state 3, is that 10 kilo Pascal and x equal to 0.9. So, essentially once you have flashed to this point you then expand it in a turbine and you go to this.

So, you essentially decrease the quality here the quality was 1 and here the quality is 0.9. The turbine should produce 1 megawatt ok. So, the whole control volume, this control volume should produce 1 kilowatt a 1 megawatt rather the 1000 kilowatt.

So, we must find out the mass flow rate of geothermal water in kg per hour. So, we must find out the mass flux ok. So, how do we go about doing this problem? So, we can do this in multiple ways, but let us start off let us see how we progress.

So, m dot 1 is the mass flux inlet again at the inlet. So, let us write down a control mass or the control volume as the flash chamber. So, for the flash chamber the mass balance is m dot 1 is equal to m dot 2 plus m dot exit. This is the mass balance for this particular control volume, the flash chip flash evaporator and m dot 1 h 1 is equal to m dot 2 h 2 plus m dot e h e. How can we write this? This is the energy balance for the flash chamber. The flash chamber does not have any working any moving object. So, there is no work extraction. So, there is no work extraction moreover a flash chamber may be assumed to be insulated. So, there can be no heat transfer as well ok.

So, here the unknowns are everything is here unknown ok, but ok. So, are the states known? Yes, h 1 is known, h 2 is also known, h exit is also known. So, in this equations again in these two equations we have 3 unknowns those unknowns are m dot 1, m dot 2 and m dot e. So, these are the 3 unknowns. So, what should be the 4th equation the 3rd equation we have only two equations 1 and 2, so, what should be the 3rd equation.

So, look if we now draw this as the control volume so, this was the CV 1 with which we could write equations 1 and 2 and in CV 2 let us write down what the mass balance is. Look the mass balance in CV 2 is obvious; whatever mass is coming in through point 2 is the same mass exiting at point 3. So, mass balance is simple m dot 2 is equal to m dot 3. So, we need not write this, the only variable here is m dot 2.

So, then let us write down the first law of thermodynamics for the control volume. So, the first law says m dot 2 h 2 is the inlet plus Q dot; so, these are the inlet energies, in flux energies this is equal to the work output plus the enthalpy at the exit. Why have I written this as m dot 2 because we have just seen that m dot 3 is also equal to m dot 2. So, I have substituted this over here.

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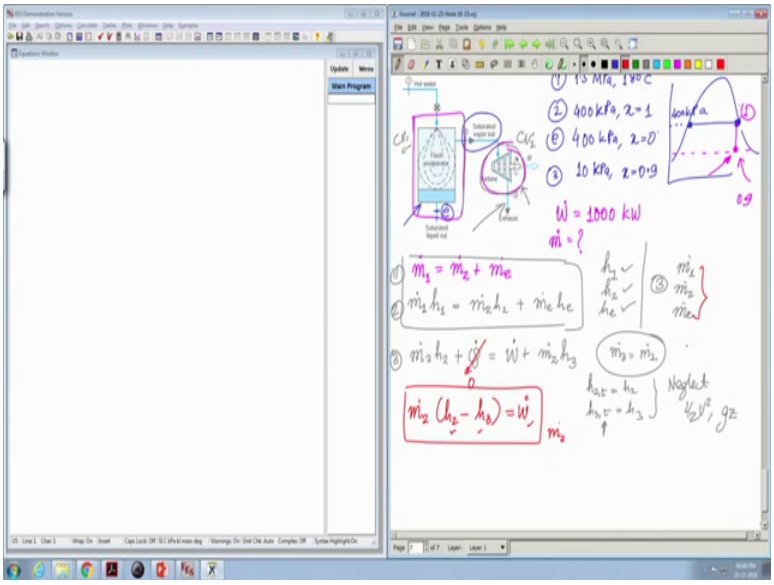

Now, a turbine unless specified is considered to be an adiabatic object ok. The process is so fast there is not enough time for heat to be transferred. So, then and also implicit in this is that h 2 total is equal to h 2 and h 3 total is equal to h 3 ideally there should be total quantities, but we can neglect the velocities. We can neglect the half v square and g z contributions from the total enthalpy and we can simply write it in terms of the enthalpy. We do not need to account for; we do not need to account for all the terms we do not need to account for the kinetic energy and potential energy. So, this term goes away and W dot remains.

So, m dot 2 h 2 minus h 3 is equal to W dot and in this particular equation W dot is known h 2 and h 3 are also known and so, in this equation the only unknown is m dot 2. So, thus we have three equations and three unknowns and we should be able to find the solution. Let us go to our computer and solve.

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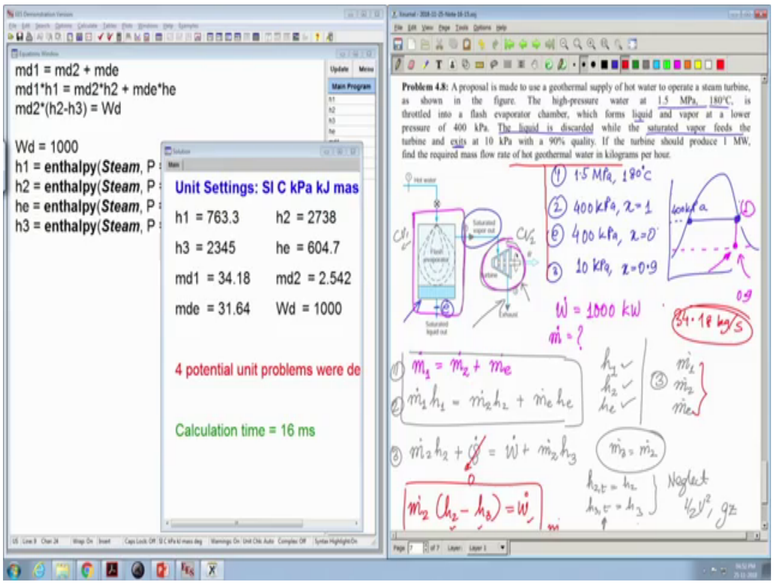

Md 1 is equal to md 2 plus me first equation m dot 1 times h 1 equal to m dot 2 times h 2 plus m dot e times he m dot 2 times h 2 minus h 3 is equal to W dot. So, W dot is the work done by the system which is 1000 kilowatt. So, W dot equal to 1000, h 1 equal to we find out from these states what the enthalpies are enthalpy a steam at P equal to 1500 kPa and T equal to 180 degree Celsius, h 2 is that enthalpy of steam at P equal to 400 and x equal to 1.

This is the extracted steam; extracted steam from the flash chamber ok. What is the h exit that is the enthalpy of steam P equal to 400, but x equal to 0 that is the extracted liquid from the flash chamber and correspondingly h 3 is the enthalpy at the exit of the turbine at the exhaust of the turbine we have a pressure of 10 kPa x equal to 0.9. So, this is what we have ok.

So, there is a small error. So, this should have been m dot e. So, the software told us that either there are more variables or more less equations and that clearly meant I have named an in named a variable wrong. These are small errors that creep in. So, anyway we are able to solve the problem and the final solution. So, the required mass of geothermal water is m dot 1 which is 34.18 kg per second. So, that is how we tackle this problem. We break down the problem into different control volumes and see how it pans out ok.

So, I hope you will try to solve more problems of this kind with the help of a computer and these kind of problems look slightly difficult, but it is not really difficult. The reason I mean you just solve it part by part and the essence of physics remains always the same it is a conservation of mass, conservation of energy and we have to make sure none of these are violated as long as none of these are violated you get the correct answer.

So, with this we conclude the problems for the first law of thermodynamics for open systems and maybe we will do some more problems later on. And with this I take leave and I will see you next time bye bye.