**Engineering Thermodynamics**
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**Lecture – 44**
**Applications. Problem Solving: Problem solving: Open system.**

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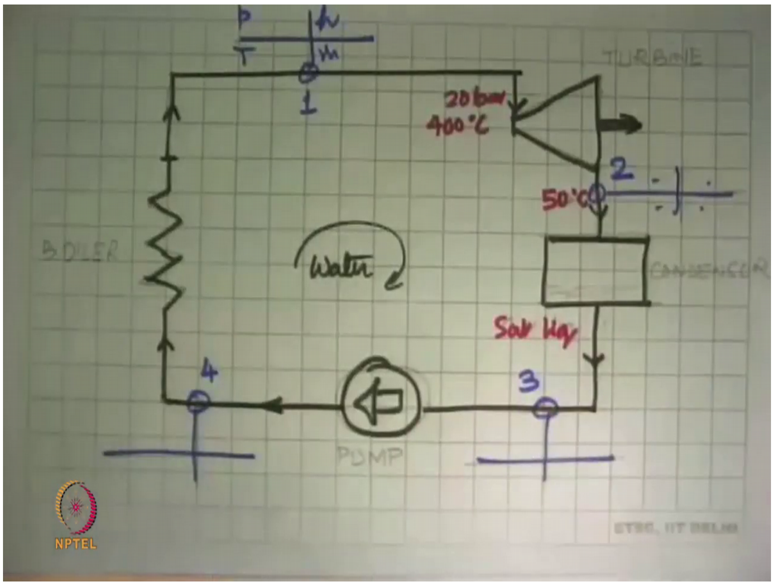


The next example I will give is of a 4 cycle that we know talked about yesterday as well. And here is the cycle that we look at. In the problem sets I have given some simple problems where we have more practice problem set in here. So, what did I is we looked at yesterday will basically a ranking cycle and that same thing I have drawn and we say that what is showing in this in water, H2O in the cycle consists of 4 components a boiler a turbine a condenser and a pump. And we connect these by a pipes which we will put there the exact of the boiler to inlet of the turbine there will be this pipe.

The flow is in this direction, the turbine is exhaust a steam and comes into the condenser where it flows over tubes carrying cold water and becomes saturated liquid and comes down. This flows into the inlet of the pump which flows into the pump. In a real power plant some of these pipes could be like 100 meters long, 115 meters long. Some pipes could be small for example, this pipe could be just like about 3 4 meters and this would be even small. So, that would be matter for us and they are given that the turbine have inlet conditions of 200 bar and 400 degree Celsius it takes times 250 degree Celsius, then it is condensed to saturated liquid.

And we want to know what is the work output of the turbine heat input into the boiler, the cycle efficiency what is the heat dissipation rate in the condenser what is the power required for the pump. All these are revived for selecting these equipment when we want to put this cycle together. So, all these calculations have been done. And these steps tell us what is the pipe diameter and the material and the type of pipe that you are going to put, but these types of conditions. So, the cycle as such what we are going to do now, is the basic first step that will not done in the design of any power plant or any correlation system or a any combine cycle power plant or any of the place there such a flow system is done.

It could be a refinery or preferment anything. This is the first diagram that we made and you put mass balance and energy balance on this. And work out what are the parameters that we are getting this. So, we do that for this particular cycle and the way we will do it is that we first say that there are 4 states. And we will say that this is state one here we have state 2 this is state 3 and here state 4. And we are assuming that in this pipe there is no change of state. So, we are assuming that pipes are ideal flows no friction no pressure drop no heat transfer with the surrounding. In reality then be a slight change decrease in pressure and temperature because it may lose heat if it is above ambient temperature. So, this analysis in this course we are assumed that to be constant. And then what we will do is we will plot all of these into a table.

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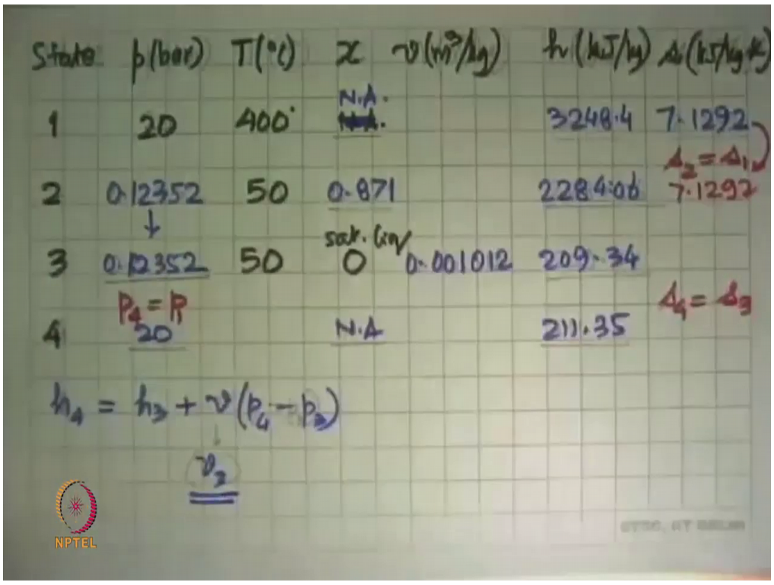


So, we make a table where in the first column we write down which is the state point that we are looking at. So, we have 4 state 1 2 3 and 4. And beside this we will list all the property for that particular state. So, first we will put pressure and units as bar. Then we will get the temperature in degree Celsius dryness fraction if applicable specific volume meter cube per kg. You know flow system we know that internal energy is not coming into the pressure.

So, we can say that I am only worry about specific enthalpy kilo joules per k g and specific entropy kilo joules per k g per Kelvin ok. Now let us first write down what do we know about this system. The first is the pressure is given at state 1 as 20 bar and the temperature is given as 400 degree Celsius. And we look at the property tables we know that this becomes superheated. So, dryness fraction is not applicable. So, this is now we are study to inform what we from this information. So, this is not applicable and since these 2 are given we can go to the property table get the specific volume.

Then get the specific enthalpy and write it there. On the table we can get the specific entropy and we can write it over there. So, these we calculated this is what was given to us. What more is given to us in state 2 they are given that it is temperature is 50 degree Celsius. And to know what is the state we see that the flow has once through the turbine which means that we use the condition that in ideal turbine s 2 will be equal to s 1. And so, this value will come here only 7.129, this thing.

Then this and this we compare it with the saturation specific entropies. And find that this is in the wet state. And so, we calculate from there and say that for this thing dryness fraction comes out to be 0.871 and the temperature pressure if the saturation pressure at 50 degree Celsius this is 0.12352 (Refer Time: 06:27) bar some of these tables will give it in kilo Pascal we have to convert it and then put it here. And specific enthalpy again we look from the table this is 2284.06. So now, state 2 is known completely, the next thing is what happens at state 3 we have told that it is completely condensed and becomes saturated liquid.

Cooling is a constant temperature process constant pressure process. In this case it is saturated state. So, wet substance going in condensing this is the constant temperature process it will go to saturated liquid; that means, x is equal to 0. So, this is saturated liquid and now from here we can again go back to the tables and pick up everything that we want, the pressure is known between the same pressure at this one 0.12352 bar specific volume 0.001012 meter cube per k g. Specific enthalpy from the tables 209.34.

Then we come to state 4 this is at the outlet of the pump. We know that the outlet of the pump the pressure has to be equal to the pressure at the inlet to the turbine because the process of heat addition is constant pressure. So, that tells us that this will be equal to 2 1. So, P 4 equal to P 1 and that a across the pump entropy is remains the same. So, s 4 is equal to s 3. So, from there we can now start putting things here that this is 20 bar dryness fraction not applicable we know this is the compressed liquid state, we need to know the specific enthalpy and for that we will use the relation in pumping we have a liquid state only.

h 4 minus h 3 is equal to P 2 minus P 1. So, we will write this as P 4 minus p 3 and this could be either v 3 or v 4 does not matter, because this specific volume (Refer Time: 08:35) we do this calculation h 3 is already known to us; h 4 will come from here it is 211.35. So now, all the specific enthalpies are known to us, all the states are known and we can visualize this cycle on the TS diagram.

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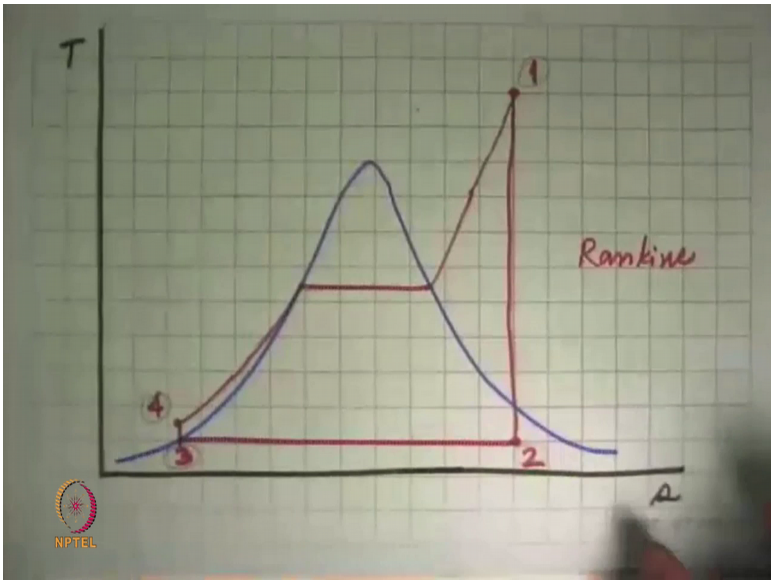


So, this is state 1 which is superheated above the critical point 400 degree Celsius. This is state 1, the turbine process is isentropic we have assume that comes down here state 2, then conversation is constant pressure constant temperature it comes 15 3.

Then isentropic compression it comes there and then there this whole process this is the peak addition process. So, that is all we can by looking at we know that this is the Rankine cycle and we now then just go back and put all the values in there.

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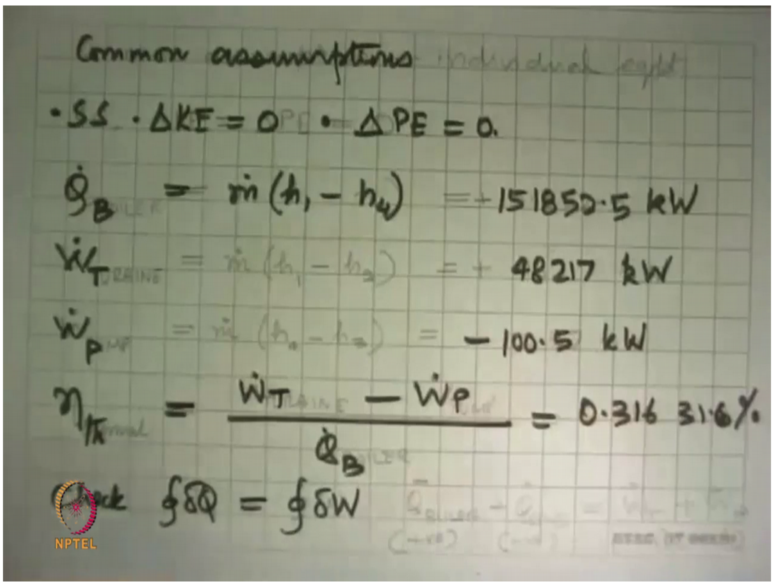

And for each equipment we will write the equation and solve it, but we do not need to do it every time. We can say that globally the common assumptions for every equipment in this is that there is steady state and that changes in kinetic energy are equal to 0 and changes in potential energy are equal to 0.

Every equipment are one things to an out loop. So, the mass flow rates are same and then we can calculate Q dot will be boiler this turns out to be 151852.5 kilo watts and the way we do that is that this is m dot h 1 minus h 4. Similarly, we can calculate the turbine work output this is 48217 kilo watts, but to the pump minus 100.5 kilo watts. And thermal efficiency the thermodynamic efficiency this is turbine output minus pump input divided by heat supplied to the cycle. And this turns out to be in this case be 0.316 or 31.6 percent. And we can also do a another check that we know that is if the cycle the second order (Refer Time: 11:13) that cyclic integral of heat is equal to cyclic integral of work.

And we can check that the taking out these numbers that that indeed the case. Sometimes it may not be exactly the thing done last digit could be asked that because of around these numbers (Refer Time: 11:30) you need to worry about that Part. So, that is how we can solve this thing and on the diagram itself, the way people would put this data that we say that here we will write the state, here we will write the pressure then temperature the specific enthalpy and the mass flow rate. So, we write the 4 numbers here similarly we can write the 4 numbers here 4 numbers over here and 4 numbers.

So, this very important information which is the starting point of design of such systems contains all the information that we require to say for instance buying a pump. And so, we say that I need so much mass flow rate I will give some margin on it. I need this as the inlet pressure this as the outlet pressure which are the pumps that I should done. This will tell us that this is the flow rate these are inlet outlet conditions which is the boiled or that much should boiled same thing with condenser same thing with turbine.

So, these are the things that I have to beginning of the designing and then finally, putting together was system like this one. There systems will have more component than this, but the process that I have just mention is same for all of this. So, that was the example that I have given. Now, we will continue taking questions, but before that let me we have to solve the question for earlier lecture.

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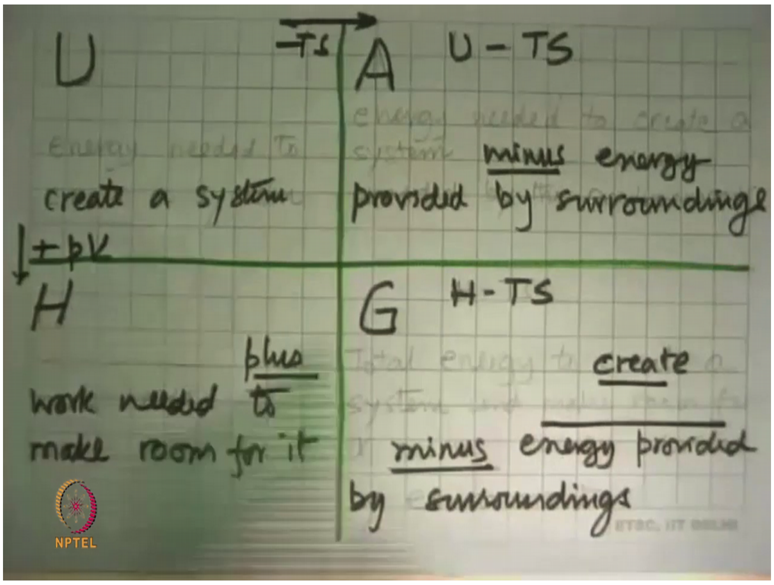


Somebody ask what is the difference between there are and Gibbs free energy or these Helmholtz energy. So, let us have if you make some of that. This is a picture that summarizes the 4 energy properties that we have learnt. U is the energy needed to create a system. This is the internal energy of the molecules, H be relevant is this plus work needed to make room for it, that different language that is there expect the different (Refer Time: 13:40).

Helmholtz free energy which we called A U minus TS this is this minus TS this is. So, this is energy needed to create a system which is U minus energy provided by the surroundings or may environment. And G which is Gibbs free energy. This is H minus TS which is the total energy required to create the system make room for it which is H minus energy provided by the surrounding this part. So, those are the 4 types of energies that will come in thermodynamics and it is not just in this thermodynamics that it will coming, but there will come in say mixtures reacting systems everywhere. These are the 4 thing that we will come across.