Basic Thermodynamics

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Lecture - 23

Vapors Power Cycle-IV

We started the discussion on the regenerative feed heating and we also discuss the ideal regenerative feed heating system, where the feed water heater from the feed pump was heated reversibly to the temperature equal to saturation temperature to the boiler pressure. This was the Rankine cycle which was made equivalent to a Carnot cycle. At the same time, we appreciated the way we understood the philosophy of the regenerative feed heating by which a Rankine cycle is converted to a Carnot cycle, where heat is added to the maximum temperature of heat addition.

Since the sensible heat part that is the heating of water from a temperature lower than the saturation temperature at the boiler pressure, up to the saturation temperature was made possible by internal heat; the heat of the expanding steam. At the same time, we appreciated the practical difficulty of obtaining it. Since we cannot place a heat exchanger in the turbine, a reversible heat transfer to achieve a temperature that is equal to the saturation temperature of the water at the boiler pressure which is equal to the inlet temperature of the turbine is not possible. One of you mentioned that the dryness fraction at the end of the expansion in the turbine was also reduced. Therefore, for all these reasons, this particular ideal regenerative feed heating system cannot be obtainable in practice; this is purely a concept.

In practice, the feed water is heated, because it was understood that if we can heat the feed water to some temperature by taking the heat from the steam, then we can increase the efficiency of the cycle, since the mean temperature of heat addition is increased. Heaters, the typical heat exchangers are made outside the turbine and the steam from the turbine at different pressures, while steam is expanding through the turbine blade and heat from that steam is being transferred to the feed water passing through the heater. There are two types of such heaters: in one heater, the steam and water are being mixed together so that they are under the same pressure, otherwise the mixing is not possible. In other type of heater known as closed heater, the steam and water do not mix with each other and water is at some pressure and steam at another. There is a separating wall and the water flows through it. Then steam is condensed on the surface and this is the way they exchange the heat transfer.

The closed heater is beyond the scope of our study. Now, we will discuss the open heaters which are relatively simpler than the closed heater. So, we will discuss the closed heater system which is implemented in practice for regenerative feed heating. Feed means the feed water and regenerative means use of heat itself to heat the system from one part and to heat the other part of the system. That is the definition of regeneration. We now come to this; closed heater.

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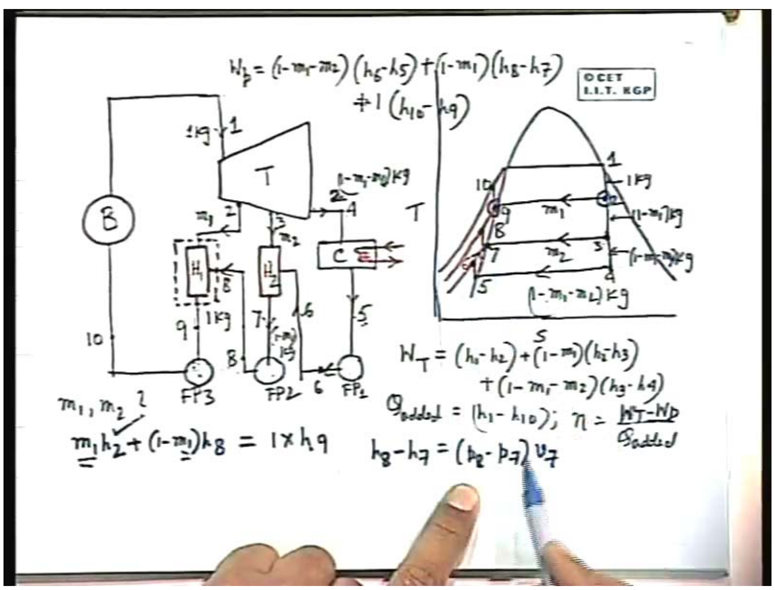

Let us consider this boiler here, and the steam enters at some pressure and temperature. The boiler pressure and temperature at this point 1 and this steam expands up to the condenser pressure 2. Let us consider point 2, which means steam after expanding to a pressure corresponding to 2, some amount of steam is blade for the regenerative feed heating. Let us consider the analysis for 1kg of flow at the inlet to the turbine. Let the flow rate be 1kg at 1. 2 correspond to certain intermediate pressure, after which pressure, the steam is being expanded. Some amount is being blade and let this point 2, 3, 4, 5. Let mass be m2, and let this mass be m1; which is being blade from point 2.

Let this steam expand to another point 3, where another amount of mass which is m_2 is being blade. Then, the steam expands to the condenser pressure 4. After condensation this point is 5; it does not matter the nomenclature. Sometimes, people go to this point with 2. Therefore, at 4 we are having 1 minus m_1 minus m_2 kg of steam. From 2 to 3 expansion of steam is taking place whose mass is 1 minus m_1 per 1kg of mass at the inlet to the turbine; then 3 m mass is blade. 3 to 4 final expansion takes place 1 minus m_1, 2 kg mass. So, it is 1 minus m_1 m_2 kg of mass condensed at the condenser pressure. That is 4 to the point 5; that means, it is condensed to the saturated liquid. There are three feed pumps: first feed pump pressurizes the saturated water to the point 6 which is equal to the pressure 3, because water is being pumped. This is heater range 2. Therefore, 6 is the pressure and correspond to 3; that means, 4 and 5 are of the same pressure. 5 to 6 is the pressure rise. If you consider this heater, it receives steam m_2 at pressure p_3 and temperature t_3. It gets water at same pressure p_6 and p_3 are same, but at the different temperatures.

The water enters, so both of them are mixed together. Therefore, if m_2 is mixed with 1 minus m_1, m_2 we get 1 minus m_1 kg of water, which is at the same pressure because mixing is taking place at the same pressure which is being pumped.(Refer Slide Time: 7:30 to 10:17 min) 3, 6, this point is 7. After pumping, this point is 8, This is being pumped to this pressure. This becomes 9 and this is mixed with m_1. So, ultimately this becomes 1kg which is the pump 10. It will be clearer if we see the diagram here; ts. After expanding to the point 2, we believe, m_1, then 2 to 3, is the expansion with 1kg. Then 2 to 3 expansions are 1 minus m_1 kg. So, 3 to 4 is: 1 minus m_1 minus m_2 kg. At 4, this is 1 minus m_1 minus m_2 kg. So, this comes to the point 5. Now, 5 to 6; this enters 6 which means, this liquid is heated; whereas, m_2 steam which is blade at this pressure is being condensed. The steam is condensed; m_2 amount of steam at this condition enters to this heater. The mass, 1 minus m_1 m_2 kg of water at condition 6 is the inlet to this heater. So, the outcome of this heater is the point which corresponds to 7. This point corresponds to point 8, this m_1 kg comes 2. Therefore, this point corresponds 9, which is the outlet of this heater. Then this is 10. This line corresponds to the pressure p_2 and this line corresponds to the pressure p; that is, the boiler pressure, and this line corresponds to the pressure $p_{3,}$ the second blading pressure.

If I write the expression for work of the turbine, work is reduced. For 1kg, if the work d_1 is h_1 minus h_2, it means the mass is changing. I am writing, work per 1kg of steam entering to the turbine plus 1 minus m_1 into h_2 minus h_3, because this path is associated with 1 minus m_1 minus m_2 into h_3 minus h_4. Heat is added from outside source, because 1 kg means h_1 minus h_2. So, you can find out that it has WT by Q added. You can find out many things from this analysis. What is Wp? The amount is 1 minus m_1 minus $m_{2.}$ So, this pump handles 1 minus m_1 minus m_2. Therefore, it is 1 minus m_1 minus m_2 into h_6 minus h_5. This pump handles 1 minus m_1 minus $m_{2,}$ it mixes 2. At 7, m_2 steam is cooled and 1 minus m_1 minus $m_{2,}$ steam is heated. It is heated to a saturated liquid, and cooled to saturated liquid; that means it is condensed. It is sensibly heated to the saturated temperature such that it becomes 1 minus m1. Therefore, this pump handles 1 minus m_1 into h_8 minus h_7, h_8 minus h_7 plus 1.

1 minus $m_{1;}$ this is this pump, so 1 minus $m_{1;}$ this is the point where it is heated. This comes here, now it is 8. These two points are repeating; that means, the two are the same points and there is no process here. Therefore, it is heated to 9, 8 to 9 sensible heating to saturated liquid, whereas m_1 is condensed and when they mix together as a result, we get at 9, 1 because m_1 is added. 9 is 1 kg here. Therefore, feed pump 3 handles 1kg. This is plus 1 into h_{10} minus h_9 and this is Wp. This whole problem or the main problem of calculation is m_1 m_2. The main parameters are: how to find out m_1 m_2? If I can find out m_1 m_2, I can find all these things. Analysis is based on kg at the entry to the turbine and I can find eta. How to find out m_1 m_2 from the energy balance of the heaters?

Let us consider the energy balance of this heater; control volume. What is the energy balance of the heater, energy coming in m_1 h_2? When you write the energy balance, you see the block diagram; not the cycle diagram. You can write the amount, which means this is 1 minus m_1 kg. This line is 1 minus m_1 kg that means 1 minus m_1 into h_8. What is the outlet outflow? This is 1kg, 1 into h_9. From this equation, you will explicitly give me m_1, provided, I know h_2, h_8, h_9. Let us find out h_2 is this point. This will be clearly told in the problem. If I know the blade pressure and it is an isentropic expansion, then I know h_2. If I am told, there is an isentropic efficiency to expansion of this blade pressure then also I can find out h_2. The actual h from the isentropic efficiency usually by isentropic expansion, I can do it straight; familiar diagram or from steam table, that means I know h_2.

This point is h_8 and this point is h_9. h_9 is similar at this pressure the enthalpy of the saturated liquid is h_9. So, I will have to know $h_{8;}$ not temperature $h_{7,}$ because h_7 I know h_8 do not know it is sub cool state. The work d is p_8 minus p_7 into v_7. I know $p_{7,}$ because I know the next blading pressure. I know p_8 that means I know this pressure and the specific volume at this blade pressure. I can find out h_8 from here. Another way of knowing h_8 is there. If you know the temperature for water, you can calculate that as kilo Joule per kg and you can multiply with cp and find out the enthalpy of the water. Actually enthalpy of the water is taken 0 at the saturated state, at 0 degree Celsius. If you consider saturated state at 0 degree Celsius, the pressure is very low. There is almost 2.0006 bar. So, at this pressure, if you heat the water from 0 degree to any temperature t, at constant pressure, then ht minus h_0 is per unit mass cp into t.

If you put the reference h_0 as 0 then the temperature at t, the specific enthalpy is cp into t. Now, you can tell that it is at this pressure, because our reference is at this pressure. But if I heat the water at different pressure from 0 degree to any temperature t, then I cannot put the reference enthalpy at 0 temperature, but the answer is the influence of pressure on change of enthalpy is negligible. Therefore, you can approximately put the value of enthalpy 0 at 0 degree Celsius at any pressure, which means, at any pressure temperature t is its specific cp into t, is a specific enthalpy. This is the other way of doing it. In the main calculation, there may be very little differences. We can find out h8 explicitly, where m_1 is known. Similarly, I can know m_2 by the energy balance of this heater. If we consider a control volume around this heater, let us write m_2 into h_3, so this is the inflow.

Another inflow is 1 minus m_1 into m_1 minus m_2, because water amount is 1 minus m_2 minus m_2, which is coming at enthalpy 6 and the outcome is 1 minus m_1 into h_7. h_3 is known, blade pressure is known. By isentropic expansion, we know h_3.

Similarly, we can find out h_6 from h_6 minus h_5, which is p_6 minus p_5 into v_5 clear. We know h_6; h_7 is again simple one. The saturated water enthalpy at this pressure that means we will have to very carefully calculate h_1. h_8, h_9 can be known from the use of steam tables or Mollier diagram and then can find out m_1 m_2. The determination of m_1, m_2 by making use of the energy balance over the heaters energy balance, enveloping the heater, considering heater as the control volume over the heater, we can find out m_1, m_2. When, m_1 m_2 is known, we can make the analysis of the cycle parameters on the basis of 1kg.

This is also the basis of 1kg and you get the result now. This is the network output for 1kg of steam flowing through the boiler or for 1kg of steam at the entry to the turbine. The analysis is as simple as this thing and this is only in our course. Let us be more friendly or easy with the calculations. If we follow a straightforward practical problem, an example problem, this theory will be again repeated through the numerical example.

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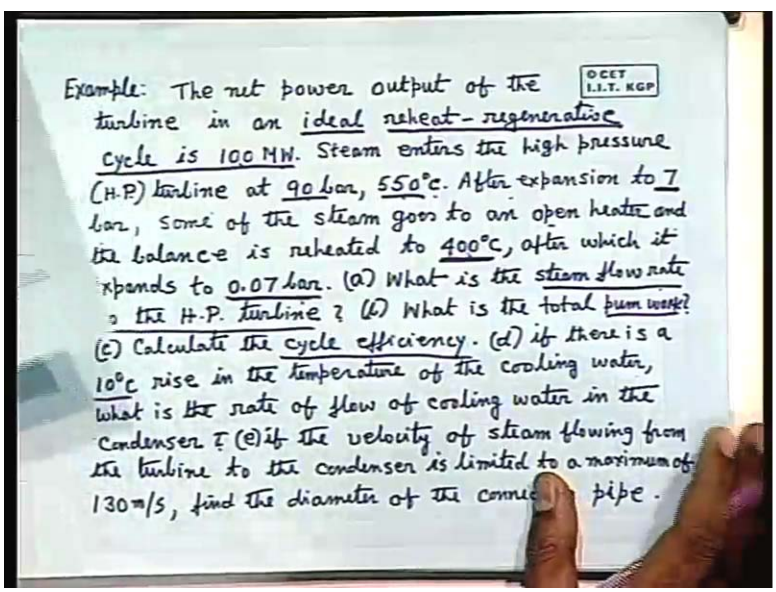

The net power output of the turbine in an ideal reheat - regenerative cycle, this ideal does not mean inside the turbine. Reheat ideal means the processes are ideal isentropic expansions and there is no heat loss from the heater. Heat transfer takes place between the steam and water that is why it is ideal. Cycle is 100 megawatt the net power out. Steam enters, there is reheat regenerative. The steam enters the high pressure turbine, at 90 bar 550 degree Celsius. After expansion to 7 bar, 90 bar is the inlet pressure. Some of the steam goes to an open heater and the balance is reheated to 400 degree Celsius. This is the inlet temperature, this is the reheat temperature after which it expands to 0.07, the final pressure is the condenser pressure.

Both reheat and regeneration is there, because the purpose is different. Reheat purpose is to increase the dryness fraction and purpose of regeneration is to increase the efficiency. Inlet pressure is 90 bar, whenever any problem will give this power output; it means, they will tell the value of this steam flow rate. That means you always analyze for unit mass of this steam at the entry and then divided it. This is not at the beginning very important. The important parameter is the 90 bar 550 degree Celsius; that means, inlet condition of this steam and the intermediate pressure 7 bar and the steam reheated, some of this steam goes to an open heater and the balance is reheated to 400 degree and then it expands to this. We have to find out the steam flow rate. I have told a steam flow rate to the HP turbine. What is the total pump work? All these things are now known to you. Calculate the cycle efficiency, if there is the 10 degree raise in the temperature of the cooling water, what is the rate of flow? What is the steam flow rate to the HP turbine, the total pump work and the cycle efficiency? Let us see this.

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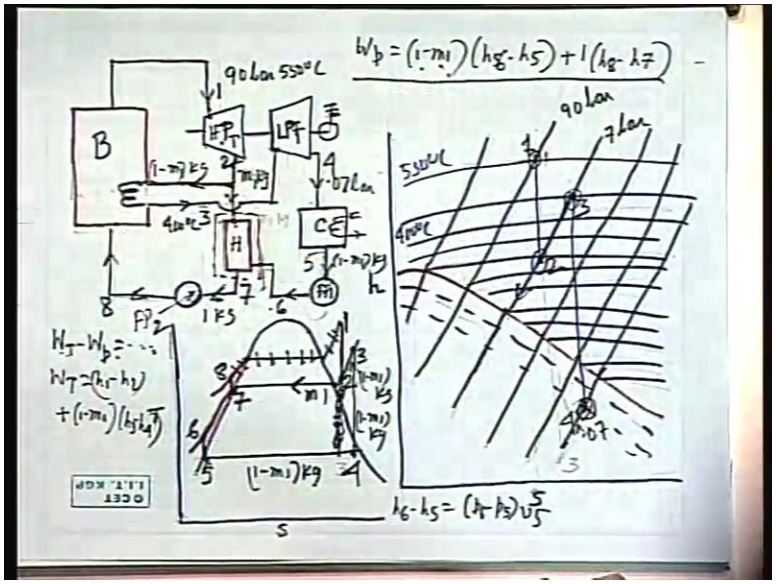

This is the boiler, this is the turbine. Now, boiler 1, which is 90 bar and 550 degree Celsius. After expansion, this is HP turbine, rather turbine T, this is LP turbine.

The steam is blade of and the rest is going to some stream which is blade of and some steam is being reheated. Therefore, some steam is blade for this and rest is reheated. The some is reheated, and some is being blade, so this is 1kg. So, this is being reheated and goes to LP turbine. So, this is the heater. It is then expanded to condenser. This is the 0.07 bar. This is the cooling water supply. This is feed pump 1, which feeds the water to the heater, then this heaters gets some m1 kg. Let m_1 kg is being blade and then 1 minus m_1 kg goes to the reheater. It then mixes ultimately 1kg is feed pump 2 and then this goes to the boiler. Let this point be 1 and this point is 2. That means 1 to 2. Then this is m_1. Let 2 be this point, it may not be dry saturated case, it may be here that depends upon the condition that will come as solution of the problem. First of all, draw the diagram in ts, draw the cycle ts diagram for your understanding.

This comes at 1 in the HP turbine, after expanding to 2, some will be going to reheater, and some is coming to the blade. m_1 kg is coming straight for this and 1 minus m_1 kg is going. Start with 1kg here, so 1 minus m_1 kg is going, and m_1 kg is going to heater. So, 1 minus 1kg is reheated to 400 degree Celsius. That means, the temperature is 400 degree

Celsius. This goes to the LP turbine and expanded to 0.07 bar. 0.07 steam; that is 1 minus m_1 kg is pumped to this pressure p. I am not showing the point. 1 minus m_1 kg is being fed to this heater. This will become m_1 kg and 1 minus m_1 kg. They come as 1kg. Now, this 1kg of water is again pumped to the boiler pressure and it goes to the boiler. This 1 to 2 is this point from 2 m_1 kg of mass is being blade, but from point 2 there is reheat which 1 will be 3? This will be 3, but this 2 to 3 is associated with 1 minus m_1 kg. From 3, you should be within this swat region that is 3 to 4. This point is 4. After 4, it is condensed. So, this point is 5. Therefore, this is 1 minus m_1 kg. This is feed pump 1 process, which gives 5 to 6, which is the pressure line. It is now heated with this blade, steam and the outcome is 7.

The 7 point corresponds to 1kg, because 1 point m_1 meets with m_1. Then 7 to 8 is this. 8 is the boiler pressure. So, this is the heating in the boiler. This is the heating. In this case, the average temperature of heat addition is not only $t_{1;}$ t_1 to t_{10}, which is much higher than t_1 to t_5. The temperature of heat addition is like that. The problem is clear, in its block diagram. How to solve this problem? If you open this steam table, it may be a little difficult, therefore always prepare hs diagram. Let me draw the hs diagram. This is the constant pressure line and these are the constant temperature lines, the things that are there in the cost and x lines.

First, you select this point 1. Let us consider this temperature as 550 degree Celsius and this pressure is 90 bar. I must find out the intersection point. I am generating here, that is the only thing in hs diagram. I just go, expanding it up to what intermediate pressure 7 bar. Let this be 7 bar, this is not in scale. So, 90 bar to 7 bar, because other pressures come 1 to 2, that means I can generate point 2. Then 2 to 3 is the constant pressure, reheating to 400 degree Celsius. Let us consider this as 3. This is for 100 degree Celsius. It is the representation of a process, mass is changing one part of this steam and another part of this steam is going. Another part of the steam is also cooled down. This is the m kg and is being cooled like this and this part is not shown in the Mollier diagram. This part is for m1 and this part is for 1 minus m_1, or if this part is m_1 then this part is 1 minus m_1, it hardly matters. From 3 to 4, let this be the 0.07. The pressure line is not in scale. 97 and 0.07, which means, I can find out also the dryness fraction, which will be 4.

1, 2, 3, 4, I will draw. 1, 2 is 1 kg. 2 to 3 is 1 minus m1 kg, where, m_1 kg is being cooled in this direction. Since, my intension is to find out h_1, h_3, g_2, h_4, which will be required in the calculation and is directly read from this ordinate state by drawing these lines. You calculate m_1 by the energy balance for this heater you calculate and then you can find out what is required. What is the steam flow rate? Means, we have to find out WT minus Wp. WT is h_1 minus h_2 plus 1 minus m_1 into 3 minus h_4 and h_1, h_2, h_3, h_4 are directly known. What is Wp? There are two pumps: one here, another here. This pump handles 1 minus m_1 into h_5 minus h_6 and h_6 minus h_5 and another one is 1 into h_8 minus h_7. Now, you see from this diagram, Wt, h_1 minus h_2 plus 1 minus m_1 h_3 minus h_4. What is h_6 and h_5? From steam table, you have to calculate both. Steam table will give the value of h_5, h_6. You can find out from the same principle; h_6 minus h_5 is p_6 minus p_5 into v_5; h_6 minus h_5 is p_6 minus p_5 into v_5. You know h_6, h_5, you know h_8, h_7, because of the pressure h_7. These are from steam table, and again, you know h_8 by the same thing. h_8 minus h_7 will be p_8 minus 7 into v_7.

When you know WT, Wp, you can find out this for 1kg of steam going through the total power, which is 100 megawatt. Why did you get this steam flow rate? What is the total pump work? For 1kg of hp turbine flow this is the power. So far, it has reversed 100 megawatt. You have to find out the steam flow rate to the hp turbine.

For 1kg of steam flow to the hp turbine, you get the power for 100 megawatt power steam flow rate, which means 100 divided by specific work output. Specific means, for 1kg flow through hp turbine. What is steam flow rate to the hp turbine? What is the total pump work? Total pump work is this. You have to find out m1 by making this energy balance across the heater for 1kg, but when you know this kg of flow rate, you can find out by multiplying total pump work. If you do on the basis of 1kg, then you will land up to the answer that this is the total pump work for 1kg of steam flow through hp turbine. The actual answer will be the total mass flow m_1; this m_1 is for 1kg. Therefore, the pump work is for 1kg of flow to the hp turbine. I have already found out the steam flow rate through the hp turbine. Multiply the total pump work like the total network is given. For cycle efficiency, you do not require the mass flow rate WT minus Wp divided by h_1

minus h_8. What is that heat transfer? If there is a 10 degree raise in the temperature of the cooling water, what is the rate of flow of cooling water in the condenser?

The rate of flow of cooling water in the condenser is the condenser heat balance; m dot cp into this delta t is equal to the heat lost in the condenser; that means, h_4 minus h_5 is equal to mass flow rate. This part is very simple m dot into cp into delta t which is 10 degree equals to h_4 minus h_5 into 1 minus m_1 into h_4 minus h_5 into the mass flow rate of

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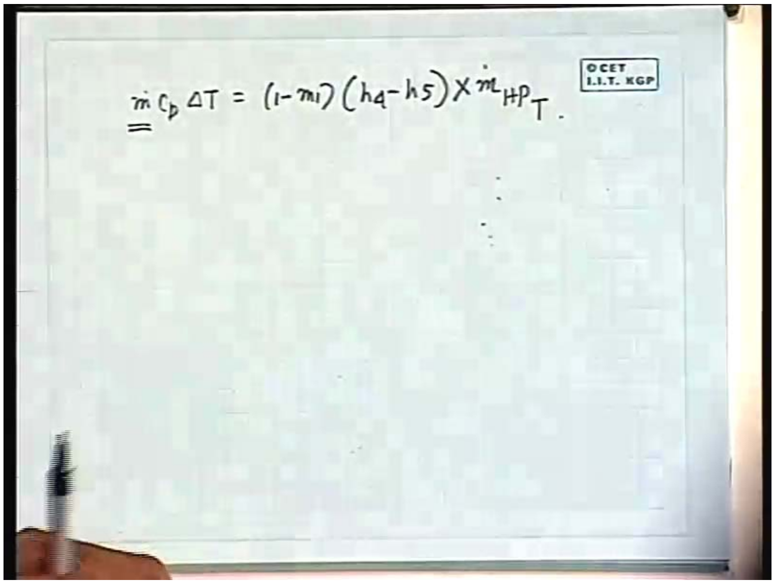

hp turbine hp m dot hp turbine. Since I will have to find out the mass flow rate of the cooling water, if you suppress it, the result is the mass flow rate of the cooling water per unit steam flowing through the hp turbine. Next part, if the velocity of steam flowing from the LP turbine to the condenser and is limited to a maximum of 130 meter per second. Find the diameter of the connecting pipe.

Mass flow rate is rho Av; rho in fluid mechanics is written like this, but here, we write like the small v this V is the velocity. You know, V_4 velocity is the given velocity of flow. So, you can find out the area. So, that is the diameter of the connecting pipe. The value of m dot is 1 minus m_1 into the mass flow rate of this thing; that means, this is per unit mass flow rate to hp turbine. m is the fraction per unit mass; so, 1 minus 1 into mass.

flow rate of the hp turbine everything is known, that is the actual mass flow. I end the discussion on this cycle. I think the ideal cycles have to start, but I do not know whether I will get time today.

How to calculate the mean temperature of heat addition without regeneration or with regeneration for any heat transfer process? Again, I repeat, for any heat addition process.

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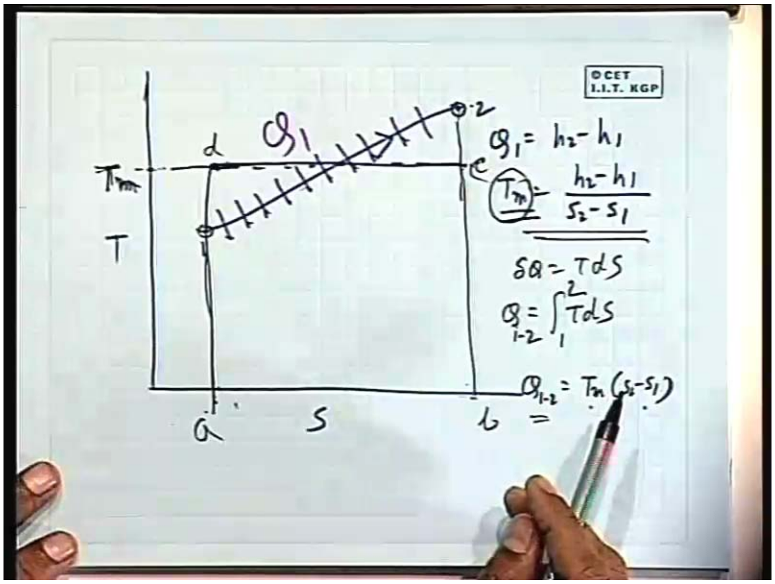

Let us consider a heat transfer process; in general, a heat addition process, where the system changes from state 1 to state 2, where the temperature increases, heat is added. Let us describe a reversible heat addition process. In a TS diagram heat addition is Q_1, where t_2 is the final temperature, and t_2 is greater than t_1. Heat added Q_1 is equal to h_2 minus h_1, which is not read in this axis. So, in hs axis, we can read this as a varying temperature. Heat addition process is not an isothermal heat addition process, heat is added such that system increases its temperature from 1, 2, and obviously, there is an increase in entropy, a mean temperature T_m. T_m is defined as h_2 minus $h_{1.}$ This is the question which can come in the examination also. s_2 minus s_1; which means that this graphically can be explained like that.

Let this area be ab 1, 2 ba is the area which represents the heat transfer during the process 1 to 2, because we know delta Q is Tds. Therefore, Q is the integral of Tds 1 to2, which is the area under this curve. If, I draw a rectangle with this ordinate steam, the value of Tm will be a projection like this. If I can construct an ordinate such that this area is now ab cd and if I can draw a parallel line to abcd so that the area abcd becomes equal to area 1 2 ab, then this ordinate we will read as mean temperature. That means this is the mean temperature of heat addition.

The physical definition is the mean temperature of heat addition in any varying temperature process is a constant temperature. The temperature at which heat was added is constant; that means, the temperature at which if this heat was added could have given the same entropy change. The same heat added could be expressed as T_m into s_2 minus $s_{1,}$ because this is the area dc ba at constant temperature heat addition is t into s_2 s_1. This is the way, one can calculate the mean temperature of heat addition.

Similar is the case for heat rejection. If this could have been a heat rejection, the same diagram from 2 to 1, we could have found out like this. Therefore, this is the way one can find out the mean temperature of heat addition.

I will close the lecture, next class I will start the air standard cycle. There is some time so I will not start any calculations, but I shall tell you what is an air standard cycle or gas power cycle not air standard gas power cycle.

I have already discussed earlier that a power cycle means a thermodynamic cycle, where power is being obtained at the cost of heat energy; this is a power cycle. When the working fluid changes its phase during operations in different process of the cycle, this is known as vapor power cycle.

The example is the thermal power plant, where the working system water changes its phase. A large class of practical power plant uses gas. Therefore, the theoretical cycles of this power plant will be gas power cycles. For example; gas turbine power plant, where the air is burnt. Fuel is burnt in the air and products of combustion in gaseous phase works and gives you the power in a gas turbine plant, aircraft engine, automotive engines that means your automobiles. We get mechanical power and working system is a gas. The thermodynamic cycles which gives mechanical power is the power cycles, the cluster of heat and the system is gas; we call it gas power cycle.

Basic definition of a thermodynamic cycle is that the initial state and final state should be same; that means, all the state properties and state variables have to be identical. Mass is one important property. If the mass of the system changes or even the constituents of this system changes during the cyclic process, even the pressure, temperature comes to the same value it does not follow ideals in actual in the definition of a cycle, because the cycle means the mass has to be same. Therefore, in all practical power plants, they do not actually reveal a thermodynamic cycle, because mass is changing. Some part is air and some part is product of combustion, where fuel has been burnt so that mass changes and moreover the products of combustion, the gas composes as they are different from that of the air. Where is the mixture of air and burnt products of the fuel?

These are not actually cycles by definition. There are other reasons by which the definitions of cycles are highlighted, why the basic definitions of heat engine cycles are there? There is an external source from which heat is added to the working fluid, which is being closely followed by a power plant that steam is working fluid, or water is the working fluid where heat is added from outside. The heat source is the gas which is known as flue gas. The product of combustion, when the fuel which is largely coal is burnt or sometimes the liquid fuel is burnt and products of combustion are not the orking system. But most of the gas power cycles, for example gas turbine cycles, as you know, these are now today popular knowledge that in your automobile cycles also the products of combustion itself is the working system.

There is no heat addition from outside; rather, a chemical energy is being into thermal energy and this thermal sort of heat, cannot be carried. Actually, heat energy which can be transferred because of a temperature difference, but that carries the thermal energy which acts just like heat and because of the processes, we get work. This is the actual cyclic operations. Do not confirm to an actual thermodynamic cycles.

These power plants are being approximated by theoretical cycles which follow all the definitions of proper thermodynamic cycles and where air is used as the working fluid throughout the cycle and heat is added from outside and rejected to the atmosphere. Burning of the fuel will generate the thermal energy; we loosely tell the generation of heat, because heat can be generated. Heat is energy intrinsic, but generation of internal energy, high temperature is being simulated by a process where air is the working fluid and it gets heat from the outside.

These are the assumptions which are made and air where an ideal gas is considered to be the working fluid of thermodynamic cycles, and they approximate or they represent the theoretical cycles of these power plants known as air standard cycles. Then, what is the difference between air standard cycles and actual cycle? All of you know that automobile petrol engine runs with auto cycles, but auto cycle is the air standard cycles, where the working fluid is air and the process is ideal.

In actual automobile cycles, the cycle operations which are performed in practice, the working fluid and then fuel is burnt in the cycle. Fluid becomes, the working system becomes the products of combustion in the air and also the processes are not ideal. These are always there. Process cannot be intrinsic or constant pressure cannot maintain. There is a pressure loss. These are being approximated by the cycles which have all ideal processes. Heat transfer takes place by heating from an external source and cooling to an external sink. Air is the working fluid behaving as an ideal gas with constant specific heat. Those cycles are known as air standard cycles and they are the theoretical cycles for those gas power plants. We will discuss those air standard cycles in next classes.

Thank you.