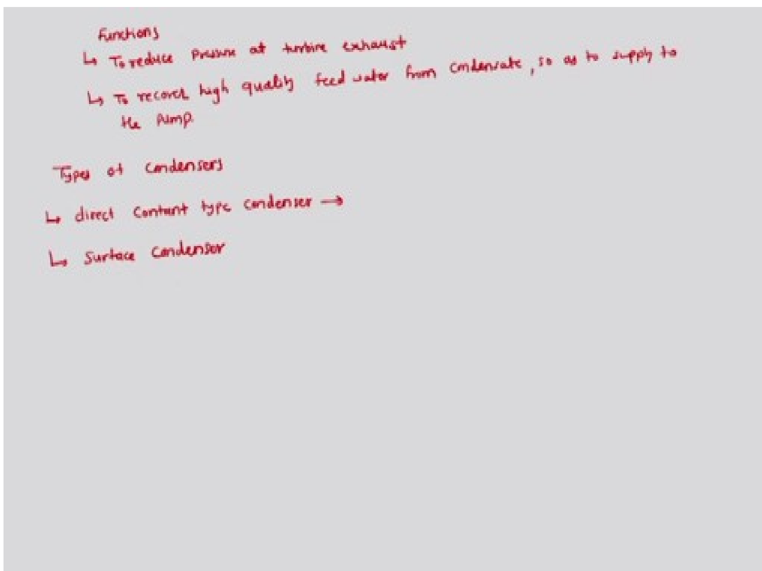
Steam Power Engineering
Vinayak N. Kulkarni
Department of Mechanical Engineering
Indian Institute of Technology - Guwahati

Lecture – 33
Condensers

Welcome to the class, topic of discussion of now is condensers, we has seen turbines, we had seen boilers, and then we had also seen the psychrometry which is necessary for understanding the processes which are very much going to happen in the condenser, okay. So, let us see how condenser works in a brief.

(Refer Slide Time: 00:54)



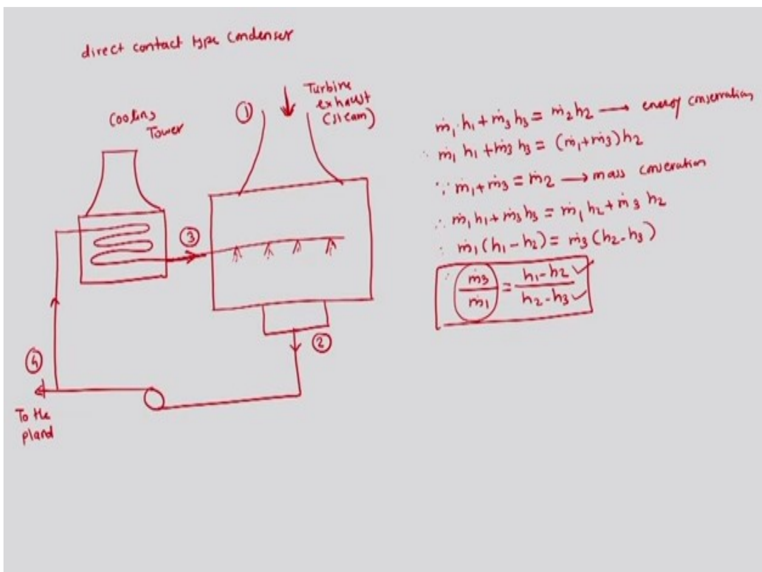
So, condenser; it has following functions; first function is to reduce pressure at turbine exhaust or to keep low pressure at the turbine exhaust, we know that if we keep lower and lower pressure at the turbine exhaust, and more and more expansion can take place for given turbine inlet condition and that will increase the turbine work output, so condenser job is to condense as much low pressure as it can such that we can have higher work output from the turbine.

Second function; the condenser is to reduce or recover high quality feed water heater; feed water, to recover high quality feed water from condensate, so as to supply to the; okay, so these are the 2 major functions of condensers. Now, we will see types of condensers, there are basically, 2 types of condensers; one is direct contact type condenser, here the water and the cooling water and the condensate are the steam at the exhaust of the turbine will be in direct contact with each other.

And then the steam will get condensed in the presence of the cooling water and then the resultant steam will be then used for further processing, so this is direct contact type condenser and there is one more which is surface condenser. Here, the cooling water and the steam will not come in contact with each other then there will be heat transfer, so this type of condenser is a heat exchanger where mostly, it is a shell and tube type.

Heat exchanger where heat will get transferred through certain medium between the steam and the cooling water, so let us see some sketches for the types of condenser.

(Refer Slide Time: 03:59)



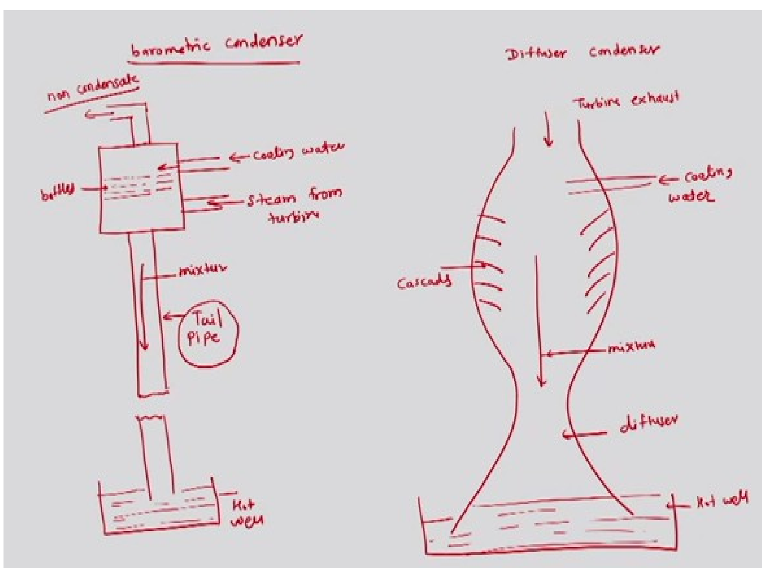
So, first is direct contact type condenser and this condenser looks like this where; so this is state 1, where we are getting turbine exhaust, so this is steam, then this is the cooling water at state 3, it is spread in the air and then this, it is state 2, which is the condensate and then this condensate will be pumped and some will be again circulated in the cooling tower, so here in the cooling tower, this water which is a cooling water will be cooled.

And then it will be passed into the condenser where it is directly coming in contact with the exhaust steam and then rest will go to the plant, so this is how, this is state 4. So, now if we try to write down equations, then we will have $\dot{m}_1$, which is mass flow rate of the steam coming from the turbine exhaust into h_1, its enthalpy is equal to $(\dot{m}_1 + \dot{m}_3)h_3$ gives us $\dot{m}_2 h_2$, so we have $\dot{m}_1 h_1 + \dot{m}_3 h_3 = (\dot{m}¿¿1 + \dot{m}_3)h_2¿$.

So, this is from the fact that since we have $\dot{m}_1 + \dot{m}_3 = \dot{m}_2$, which is mass conservation and we are working here on energy conservation, so we can have $\dot{m}_1 h_1 + \dot{m}_3 h_3 = \dot{m}_2 h_2 + \dot{m}_3 h_2$, so we can have $\dot{m}_3 h_3$ minus; we will have $\dot{m}_1 h_1 - \dot{m}_3 h_2 = \dot{m}_1 (h_1 - h_2) = \dot{m}_3 (h_2 - h_3)$, so we will have $\frac{\dot{m}_3}{\dot{m}_1} = \frac{h_1 - h_2}{h_2 - h_3}$.

So, we would know this enthalpy difference, which is the difference at the inlet and at the outlet of the condenser and then we can know what is the enthalpy difference for the cooling water, so as to condense the exhaust steam, then upon that we can find out the ratio of mass flow rates and then that will give us amount of cooling water to be circulated, so this is how we can work. Now, this is a direct contact type cooling; direct contact type condenser.

(Refer Slide Time: 09:16)



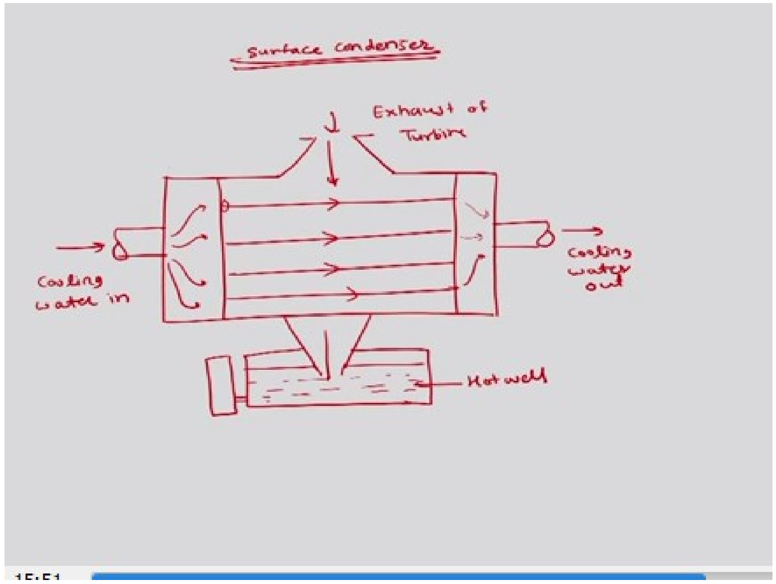
Now, next we can have similar way, one more condenser, again in direct contact type which is called as barometric condenser, this condenser again has direct contact between the steam and the cooling water but here, this mixture is passed through a long tail and that tail will put this mixture into a well, so this is tail and then this is tail pipe and this is hot well and from here, we are getting cooling water and then this cooling water will splash over the baffles, so these are called as baffles.

And then we will have steam from the turbine and then there will be some non-condensate, this is non-condensate, so this cooling water would come out, it will get splashed and then it will mix with the steam and then steam will get condensed in this process and then it will, mixture will come down, this is mixture, it will come down and get settled in the well, these height of the tail pipe is very much is required such that we will have rise in the pressure of the mixture.

So, the mixture will come at low pressure and in the process of condensation and passing through the tail pipe of the condensation; passing through the tail pipe, it will rise its pressure to the atmospheric pressure but this barometric condenser needs a long pipe for the pressure building instead of that sometimes, diffuser kind of condenser which also used, where we will have these as the hot well and this is the diffuser.

Then there will be baffles or also called as cascades, this is turbine exhaust, this is cooling water and then this are called as cascades, here this mixture while passing through the diffuser rise its pressure, so this is how, we will have diffuser type of condenser which will reduce the height of the tail and then we will have surface condenser and that surface condenser will not have direct contact of the steam and water.

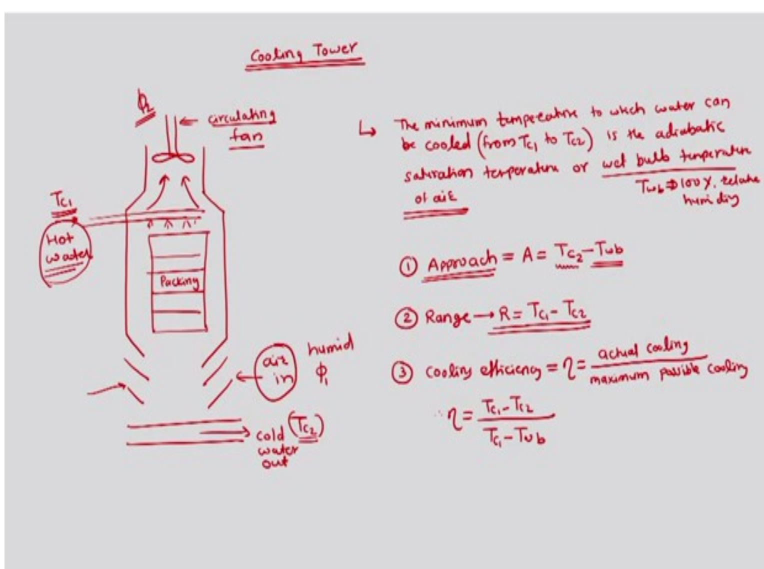
(Refer Slide Time: 13:20)



And then we will have the process of condensation without contact, so here are the shell and tube type of heat exchanger, where we can sketch a typical non-contact type or surface condenser, here we are having exhaust of turbine, this will have cooling water in this is cooling water out and in this phase, this is not the mixture, only steam will get condensed and then it will get settled into the hot well, this is the typical surface condenser which is a heat exchanger where we will have water pipes which have the ability to transfer the heat from the steam to the water.

And this is similar what we have seen in case of boilers, having said this we will move now towards the cooling tower.

(Refer Slide Time: 15:54)



We have seen that cooling tower is a part of condenser and this cooling tower is very much required to cool the cooling water, cooling upon in contact or after having heat transfer from the steam will get heated and that cooling water needs to be re-circulated into the condenser, so we have to remove the heat from the cooling water and that removal of the heat will be taken in the cooling tower, where we will use the atmospheric air to cool the water in the cooling tower.

And then typical sketch of cooling tower is like this where we will have; so hot water will come into the cooling tower and then that would get sprayed over the packings and then these will get splashed and come in contact with the air which is circulated through a circulating fan which will come from the bottom and then will get heated and then it will remove; get remove from the top, so in this process, water will get cooled and then this is the cold water out, this is a typical sketch of the cooling tower.

So, here we are cooling the cooling water which is not part of the Rankine cycle is having water which will get evaporated in the boiler then expanded in the turbine and condensed in the condenser, that water which is getting condensed into the condenser is having this heat transfer to this cold water and this cold water in this process will become hot, so the same water which is used in the condenser to extract the heat from the steam is now hot after extraction of heat.

This water should have again been passed to the condenser, so for that it is cooled in the cooling tower with the atmospheric air. Now, there are certain things which we should know that the minimum temperature to which water can be cooled from T_{c1}, which is T_{c1}cooling water temperature, this is T_{c2}; to T_{c2} is the adiabatic situation temperature or wet bulb temperature of air, so this point is very much to understand that the air which is coming in is already humid.

It will have certain ϕ_1 and this ϕ_1 of air after having mixing or after having mixed and transferred heat from the water will have certain ϕ_2, so in this process, we are cooling the water but we cannot cool the water if ϕ_2 becomes 1, so this is wet bulb temperature, so this point is important that at this wet bulb temperature, we are having 100% relative humidity. So, we cannot cool beyond this, so there are certain concepts for the cooling tower.

And first concept is called as approach; approach of cooling tower is called as A and that is equal to $T_{c2} - T_{wb}$, this is the temperature of the cooling water at the exhaust of the cooling tower after the process of cooling minus T_{wb} which is wet bulb temperature corresponding to $\phi = 1$, this is called as approach of cooling tower. Second is called as the range of cooling tower, in this range is defined as R, this is equal to $T_{c1} - T_{c2}$.

So, the actual cooling what cooling tower does from T_{c1} temperature to T_{c2}temperature case is called as range of cooling tower, then there this third concept which is called as efficiency; cooling efficiency and then this is eta and this equal to actual cooling divided by maximum possible cooling, so efficiency of cooling tower is actual cooling is $T_{c1} - T_{c2}$ which is range and maximum possible is $T_{c1} - T_{wb}$, so that is wet bulb temperature.

So, this is what the efficiency of cooling for a cooling tower, now we can use the concept of pschrometry to understand the different heat transfers and different masses of the airs and the humid air and also for the water vapour, so we can use this concepts for better understanding of the cooling towers and also for the condensers, thank you.