Steam and Gas Power Systems
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Module No # 03
Lecture No # 13
Performance of Boiler

Hello I welcome you all in this course on steam and gas power systems today we will discuss about the performance of boilers. Now the performance of boiler there many terms through which we can judge the performance of boiler.

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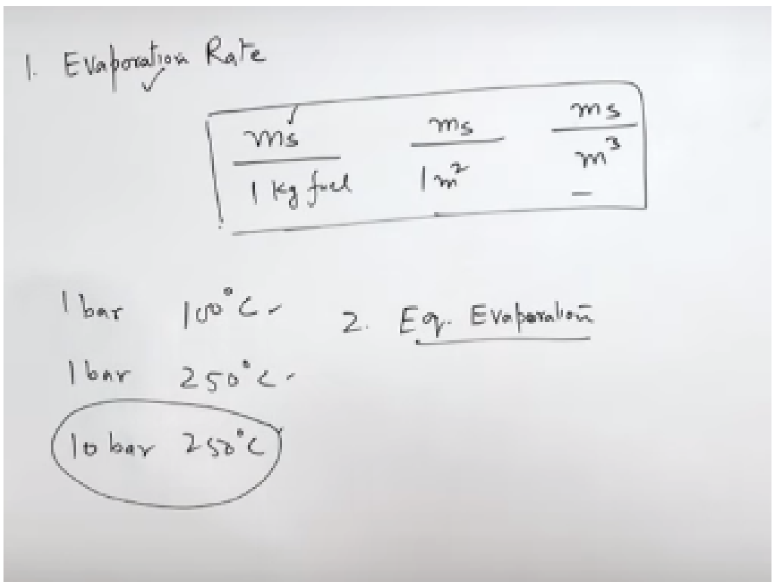

The number one is evaporation rate mass of the steam produce by the boiler divided by per KG of fuel or mass of the steam produced by the boiler per meter of heating surface area or mass of the steam produced by the boiler divided by volume of the grate that is also in meter cube. So either of these three we can express the evaporation rate but the evaporation rate problem with the evaporation rate is that.

The evaporation rate does not represent true performance of the boiler the reason being we have taken mass of the steam. If we take 1 KG of the steam at 100 degree centigrade and 1 KG of steam at 250 degree centigrade at 1 bar and at 10 bar if we take steam at 250 degree centigrade in all these three conditions the energy with the steam will be different and the highest energy will available with this steam but this expression does not take into account this phenomena.

That is why the evaporation rate is not considered as of two representatives of the boiler performance. Now this is term is placed by equivalent evaporation now equivalent evaporation is in terms of energy. It means energy going with the steam and energy spent in order to have that steam.

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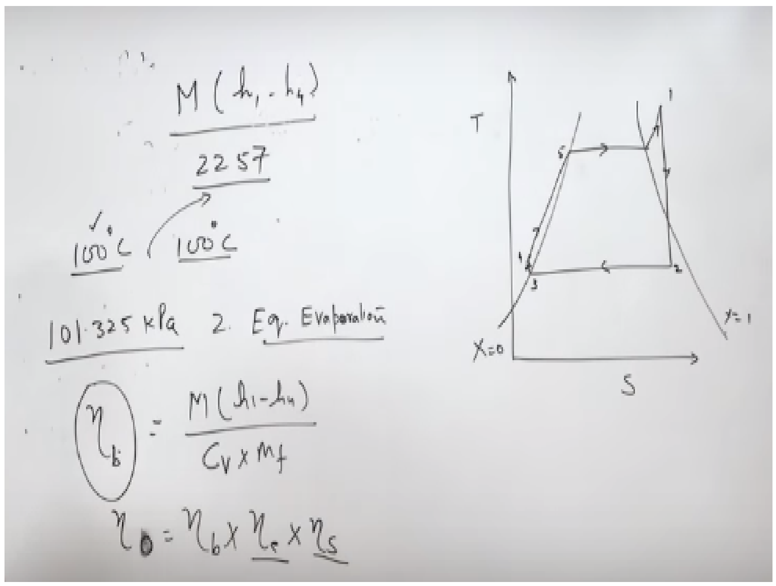

It means the mass of the steam produced is M then H G - HF that is the energy going with this steam. If you look at the rankine cycle then pressure and entropy then state one state two state three four and state 5. Heat edition in the rankine cycle takes place in state between the state four to state one the feed water goes to the boiler at state four and state one.

So here also accordingly with reference to this diagram this is going to be heat taken away by the steam divided by mass of the fuel burn and (()) (03:44) value of fuel so this is known as so this is known not equivalent to evaporation rate. Now this is divided by this is divided by 2257 is enthalpy of evaporation of water at 100 degree centigrade at atmospheric pressure at sea level one point sorry a 101.325 kilopascal right.

At this pressure right if the water is available at 100 degree centigrade the entire water is converted into the steam at 100 degree centigrade the latent heat is going to be 2257 equivalence to this the evaporation rate is taken this is the two representative of the performance of the boiler right. Another term is boiler efficiency every equipment's has to have an efficiency.

So the boilers also having efficiency so equivalent evaporation rate gives idea about how much energy going with the scheme right. So we starting with evaporation rate evaporation rate is the steam reduced and the mass of the steam produced and the ratio of mass of the steam produced and energy is spent in producing that speed. So evaporation rate does not seem to be the true representative of boiler performance.

Then we have come to the another term equivalent evaporation rate that is energy going with the steam divided by latent heat of evaporation at 100 degree centigrade atmospheric pressure. Now we will come to efficiency of the boiler, efficiency of the boiler is energy going with this steam mass of this steam H1 - H4 divided by (()) (5:55) value of tool and mass of the fuel burn energy is spent and energy is used in generating the steam that is the boiler efficiency.

If all super heater and economizer they are housed in one shell then no problem if there has a separate entity then boiler efficiency the total then it is called overall efficiency is the efficiency of the boiler multiplied by efficiency of the economizer multiplied by efficiency of super heater right. And all are taken in terms of the ratio of energy suppose an example economizer energy available with the flue gases, energy taken away by water.

So energy taken away by water divided by energy level with the flue gases will give the efficiency of the economizer accordingly the efficiency of the super heater can also be calculated. Now normally loses in the boilers as we have discussed in earlier lecture also may vary from 10% to 20% and 25% now the issue is where this heat is going.

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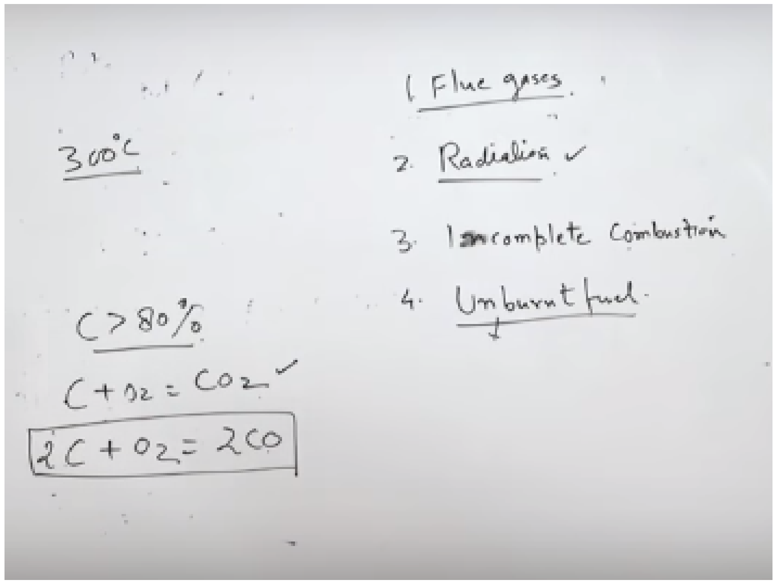

That the energy is converted into the steam then where this heat is going now this heat is going with number one flue gases because the temperature of flue gases is quite high when they are drumming out of the boiler it is of the order of 300 degree centigrade it is approximately three 300 centigrade ok. So this heat is going with the flue gases though we try to trap this heat through economizer and pre heater but still substantial amount of heat go with the flue gases.

Number two loss due to radiation the boiler surface temperature is higher than the surroundings so there is a heat loss surroundings per radiation or convection. So that also amounts to the heat loss of the boiler number three is incomplete combustion now incomplete combustion means the carbon normally if we take solid fuel right that the carbon is greater than 80% ok.

So the carbon is converted to carbon di oxide and carbon is also converted into carbon monoxide and this conversion of carbon in monoxide r this is known as incomplete combustion right. And the heat generated for the oxidation on carbon in two carbon monoxide is less than the heat generated for the oxidation of carbon di oxide. So there is a net heat rendition loss also.

So due to this incomplete combustion there is a heat loss now there is unburned fuel some of the fuel remains unburned in goes to ash pit right. It does not participate in the combustion so that also amounts to the loss because when we are total energy is the mass of the fuel used multiplied by the (()) (09:42) fuel. If the fuel is going to the ash pit that fuel is not participating or not contributing him increasing the energy of feed water.

So all this factors a cumulative effect of all this factors turns out to be forms of losses in the boiler and well-designed boiler will have efficiency between 85 to 90%.

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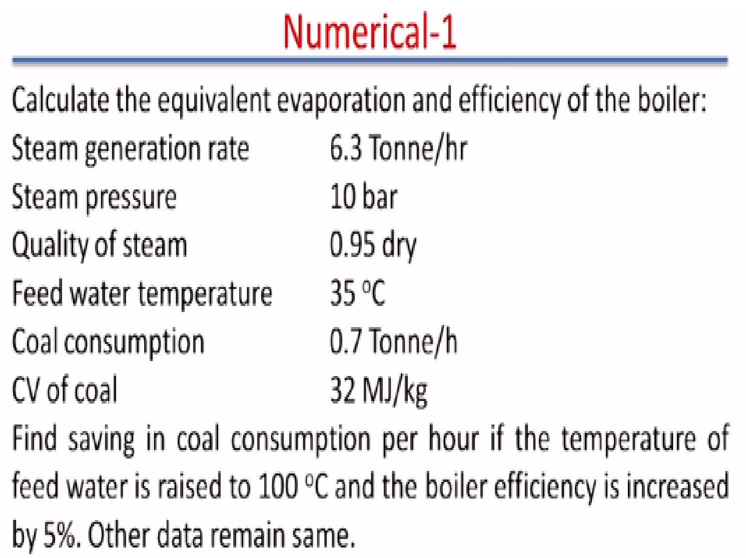

Now in order to understand this we will solve one short numerical it says that the statement of the problem is calculate the equivalent evaporation and efficiency of the boiler. A steam generation rate is 6.3 tones per hour a steam pressure is 10 bar quality of the steam at the exit of the boiler is .95. Feed water temperature the water which is going to the boiler is 35 degree centigrade.

Coal consumption it is coal is used as fuel and the coal consumption is .7 tone per hour calorific value coal is also given 30 mega joules per kg. Find the saving in coal consumption per hour if the temperature of feed water is raised to 200 degree centigrade and the boiler efficiency is increased by 5 % other data remains same. So there is a modified condition when the feed water temperature raised to 100 degree centigrade then the boiler efficiency is also improved simultaneously.

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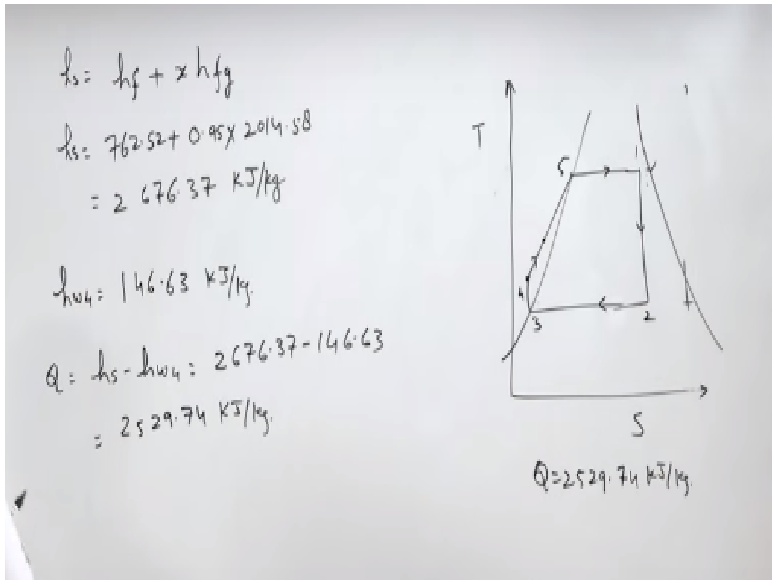

It means in a rankine cycle in this rankine cycle initially feed water was given at state four 35 degree centigrade then feed water was heated up to 100 degree centigrade in second condition so state is somewhere here and final state is remaining same right. So we will start with enthalpy of the steam enthalpy of the steam or enthalpy of the steam that enthalpy now here in this case the quality of the steam is .95 drive it will not be superheated.

So steam is expanded somewhat in this fraction one and two right so enthalpy of the steam is enthalpy of the fluid + X enthalpy F latent heat of evaporation. Steam is produced at 10 bar so we will take properties at 10 bar properties are given here HF is 762.2 and latent heat is 2014.58. So HS enthalpy of the steam 762.52+ 0.95 multiplied by 2015.58 right.

And through this we get finally the value as 2676.37 kilo joules per KG. This is enthalpy of steam at state 1 now enthalpy of water is state 4 is water is available at 35 degree centigrade right and 35 degree saturated enthalpy at saturated steam is 146.63 kilo joules per KG.

It is sub cool liquid right it is sub cool liquid and enthalpy is taken as 146.63 so the heat added Q is HS - HW4 = 2676.37 – 146.63 and that is going to be equal to 2676.374 kilo joules per KG right. So heat added Q = 2529.74 kilo joules per KG.

Now steam generated per KG of coal steam generated per KG of coal is steam generation rate is 6.3 tones per hour.

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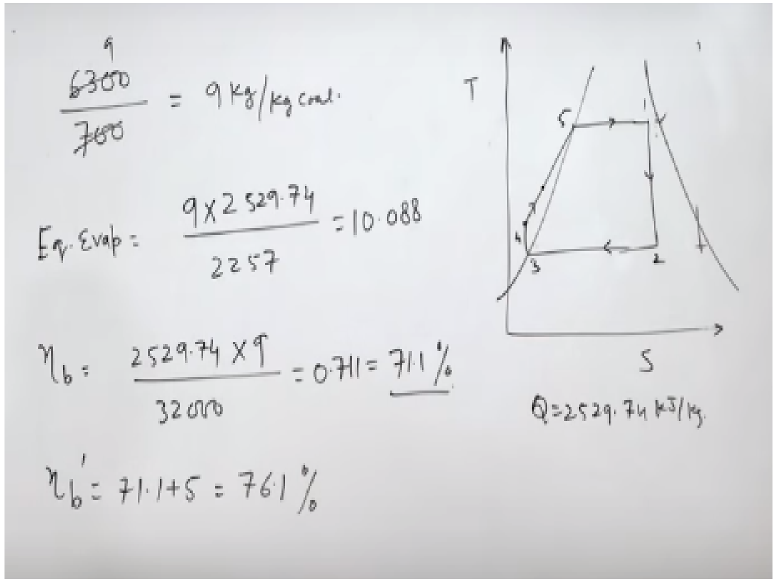

So steam generation rate is 6.3 tones per hour or 1600 KG per hour and coal consumption is .7 tones per hour .76 KG per hour. So per KG is burnt per KG of coal then we will be getting 9 KG of a steam per KG of coal. So equivalent evaporation is in this case is mass of the steam produced multiplies by energy spent in converting modern into the steam it is 25229.74 divided by 2257.

And that will give the equivalent evaporation as 10.088 right now efficiency of the boiler. Now if we want to calculate efficiency of the boiler in this case two 529.74 that is heat taken away by 1 KG of water multiplied by 9 divided by calorific value of the fuel 1 KG of fuel that is 32 mega joules per KG. So 32 kilo joules thirty two thousand kilo joules and if we solve this.

So it is going to be 0.711or it is going to be 71.1 % so that is the efficiency of the boiler. Now new condition is efficiency is 71.1 + 5 first of all so it is 76.1 % that is new efficiency and another condition is water is heated up to 100 degree centigrade right.

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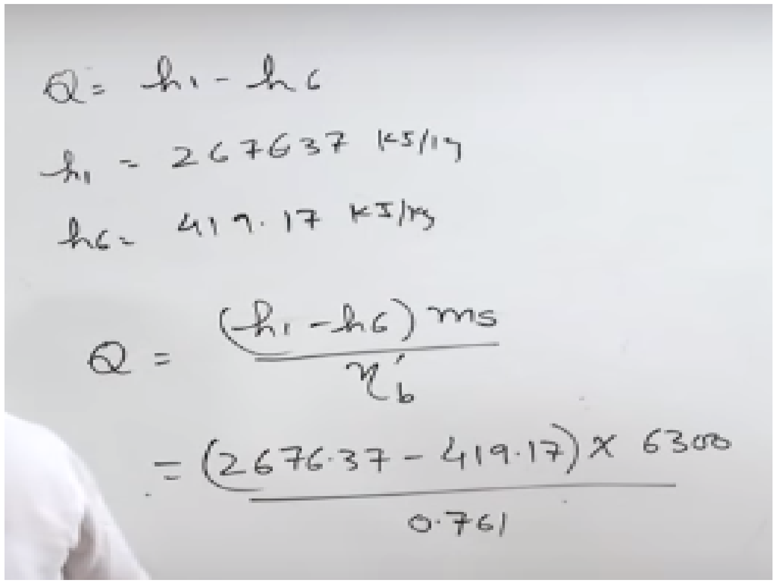

And water is heated up to 100 degree centigrade means heat added is H1 - H suppose it is heated up to 100 degree centigrade is six H1 - H6 right. So in modified condition it is going to be H1 was in previous case H1 was 2676.37 kilo joules per KG H1 we have already calculated it. Now H6 is again we will have to refer this steam table at now it is 100 centigrade right.

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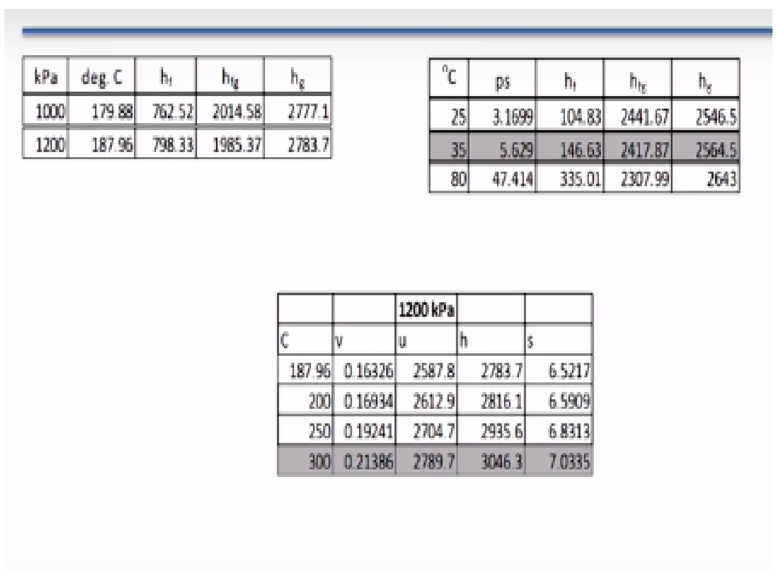

kPa	deg. C	h_f	h_{fg}	h_g
1000	179.88	762.52	2014.58	2777.1
1200	187.96	798.33	1985.37	2783.7

°C	ps	h_f	h_{fg}	h_g
25	3.1699	104.83	2441.67	2546.5
35	5.629	146.63	2417.87	2564.5
80	47.414	335.01	2307.99	2643

		1200 kPa		
C	v	u	h	s
187.96	0.16326	2587.8	2783.7	6.5217
200	0.16934	2612.9	2816.1	6.5909
250	0.19241	2704.7	2935.6	6.8313
300	0.21386	2789.7	3046.3	7.0335

So 100 degree centigrade property is or it is heated up to 100 degree centigrade properties are not there but I have property with me 100 degree centigrade. Now feed water is heated up to 100 degree centigrade so H6 is 419.17 kilo joules per KG. Now here in this case heat supplied in the boiler in modified case is Q = H1 - H6 multiplies by mass of the steam divided by efficiency of the boiler which is modified.

Now H1 is 2676.37 H6 is 419.97 mass of the steam produced is 6300 modified efficiency of the boiler is 0.761 and this will give the heat supplied as.

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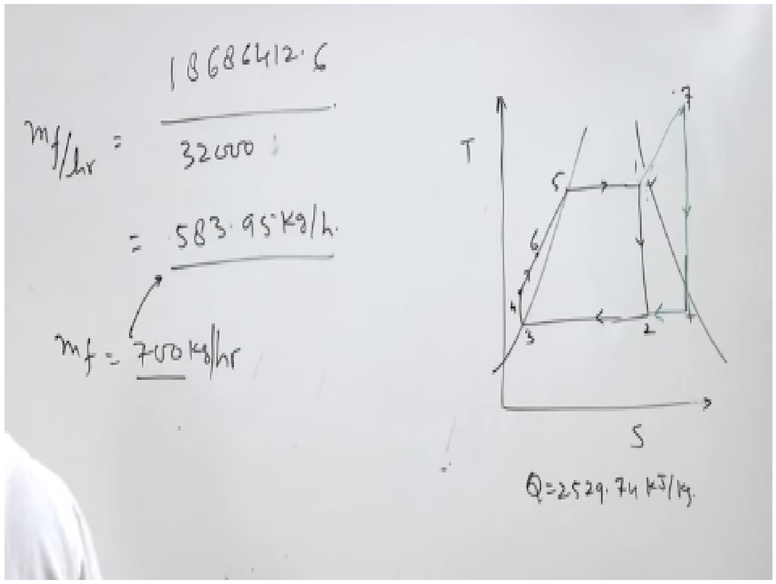

Now we will find mass of the fuel burned per hour right mass of the fuel burned per hour is heat supplied heat supplied is the simplification of this that is going to be 18686412.6 divided by calorific value of fuel that is 30,000 kilo joules per KG and that's it calorific value of fuel. So this is give the mass of the fuel is 583.95 five KG per hour.

So what you have done here we have taken the modified boiler efficiency modified heat edition then H1 - H6 multiplied by the steam mass of the steam produced per hour. This will give us how much energy will be required per hour divided by calorific value of fuel because it is mega joule mega joule is converted into the kilo joules and finally we got the mass of the fuel required per hour.

Now in the previous condition the mass of the fuel was how much 700 KG per hour so you can see how much fuel can be saved in with the modified conditions of the boiler. Now after this we can take another numerical and here in this numerical the steam pressure is 1.2 per mega pascal. Quantity of steam leaving the boiler quality of the steam leaving the boiler is .97 so it is wet steam.

Temperature of the steam is leaving the super heater so super heater is also used in addition to the boiler that is 250 degree centigrade quantity of coal fire is 75 KG per hour feed water supplied is 115 KG per minute.

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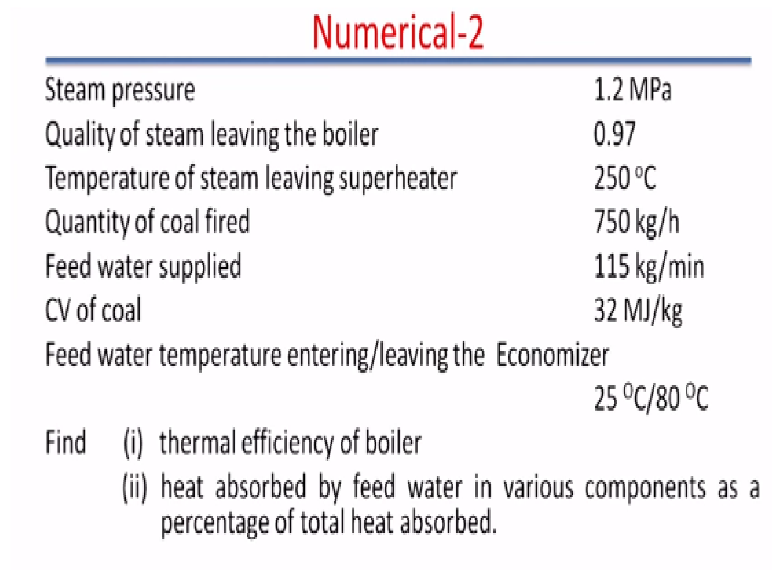

So whatever feed water is supplied we assume that this is the amount of heat sorry the steam generation calorific value of coal is here is 32 mega joules per KG. Feed water temperature entering leaving the economizer so economizer is also used in this boiler. So feed water heater and economizer is also used so that is 25 degree centigrade to eight degree centigrade.

Fine thermal efficiency of the boiler so this boiler has super heater right super heater this state seven and then vapor is expanded so instead of having a (()) (22:05) boiler there is a super heater also and in super heater the vapor are heated and then their expanded in the turbine right. So in order to find a solution for this problem first of all we will see how much the steam is produced per KG of coal.

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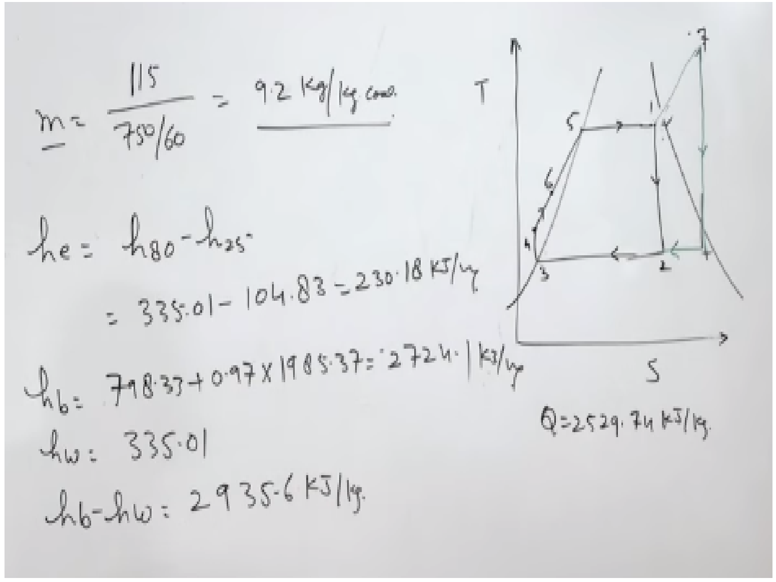

So steam produced here is a steam produced is 115 KG and that is KG per minute and coal is 1 KG per hour divided by 750 divided by 50 so that will give mass of the steam produced per KG of coal that is 9.2 KG per KG of coal. This is mass of the steam produced by burning per KG of coal heat added in economizer is H 80 - H 25 that is going to be = 335.01– 104.83 and that = 230.18 kilo joules per KG.

Heat added in the boiler is enthalpy at state 1 and enthalpy of feed water so enthalpy of state 1 is we can take from here at 1200 kilo pascal then enthalpy of liquid is 798.33 and latent heat is 1985.37. So we will take here 798 .33 + 0.97 into 1985.37 it turns out to be 2724.1 kilo joules per KG.

Enthalpy of the feed water is 335.01 HT that is 335.01 and HB - HW will give us how much heat is added in the boiler and that is going to be = 2935.6 kilo joules per KG. Now heat is also added in super heater so heat added in super heater is enthalpy of superheated vapor so 1200 kilo pascal and 25 degree centigrade.

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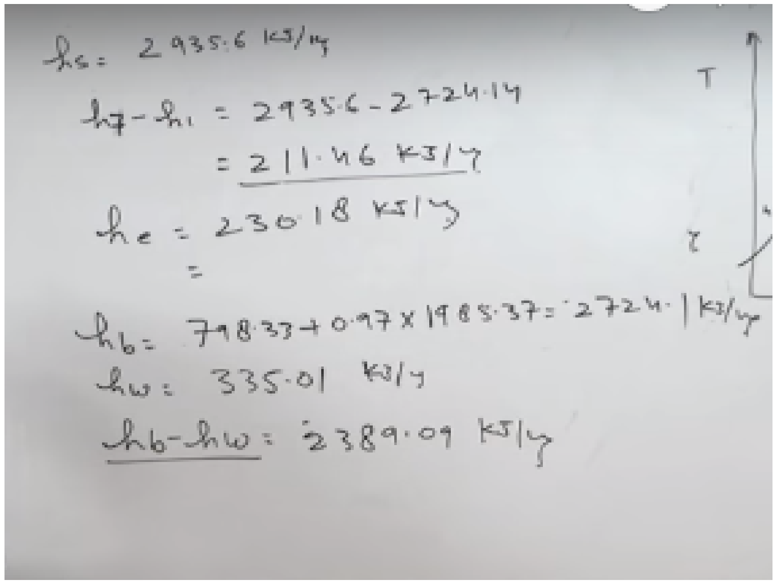

So enthalpy is 2935.6 kilo joules per KG so heat added in super heater is HS - or H7 - H1 that is 2935.6 - this 2724.14 that enthalpy at state 1. And that will give heat added in super heater is 211.46 Kilo joules per KG. So this is heat added in super heater there is correction here minus this is going to be not 2935 it is 2724.1- 335.01.

2389.09 right so this is heat added in boiler this is heat added in super heater heat added in economizer already calculated and heat added in economizer was 230.18. Now we will add these three component this one this one and this one and this will give the total heat added in the process and the total heat added in the process is Q 283.77 kilo joules per KG.

Now once we have the value now we have to find out sorry thermal efficiency of the boiler now once we have this value and we know the calorific value of fuel also 30 mega joules per KG. Now this is multiplied by how much steam is generated.

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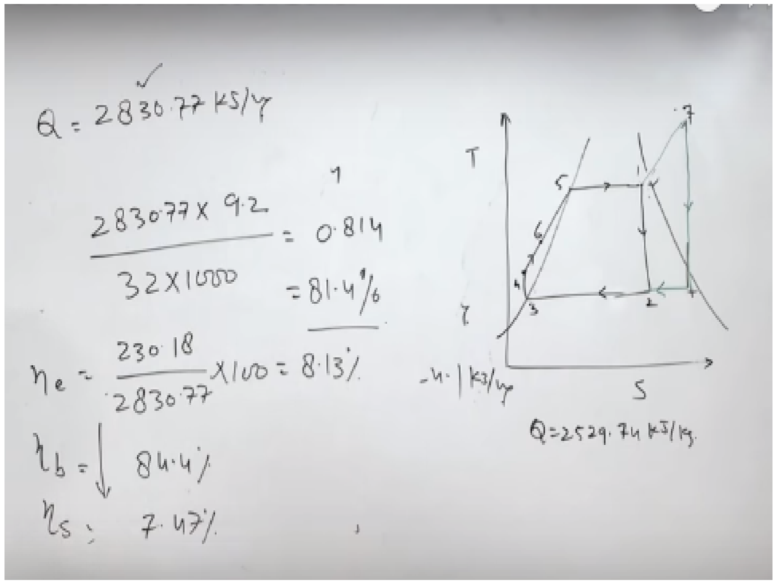

So Q in order to find the efficiency Q two 830.77 multiplies by 92 amount of steam produced by burning 1 KG of coal divide by 32 into 1000 and this will give the efficiency as 0.814 or 81.4 %. And the second term is heat absorbed by the heat water in various components as a % of total (()) (27:47) this is total heat and for individual component.

We know how much heat is absorbed for example for economizer it is 230.18 divided by 2830.77 seven multiplies by 100 that will give 8.13 % similarly for other components boiler and super heater we can find the efficiencies. The efficiencies are 84.4 % and 7.47 %. That is amount of heat absorbed in different component right now this is all for today thank you very much.