Steam and Gas Power Systems

Prof. Ravi Kumar
Department of Mechanical and Industrial Engineering
Indian Institute of Technology - Roorkee

Module No # 04
Lecture No # 16
Boiler Trial

Hello I welcome you all in this course on steam and gas power systems today we will start with the boiler trial is the account of I mean the analysis of the boiler is done and it is account of where from the heat is coming and where the heat is going it is total balance sheet of heat transmission of the boiler.

How much heat is going with the flue gases in fact how much heat is going with the burn product how much heat is going with the excess air how much heat is going with the water vapor how much heat is loss to the surroundings it is by difference only how much heat is supplied to the to the boiler burning the fuel all this are taken to account and balance sheet is created.

So before we go to the boiler trial we will start with the flue gas analysis now flue gas analysis is very important because with the help of flue gases analysis you can directly find how much air has been used in burning the fuel.

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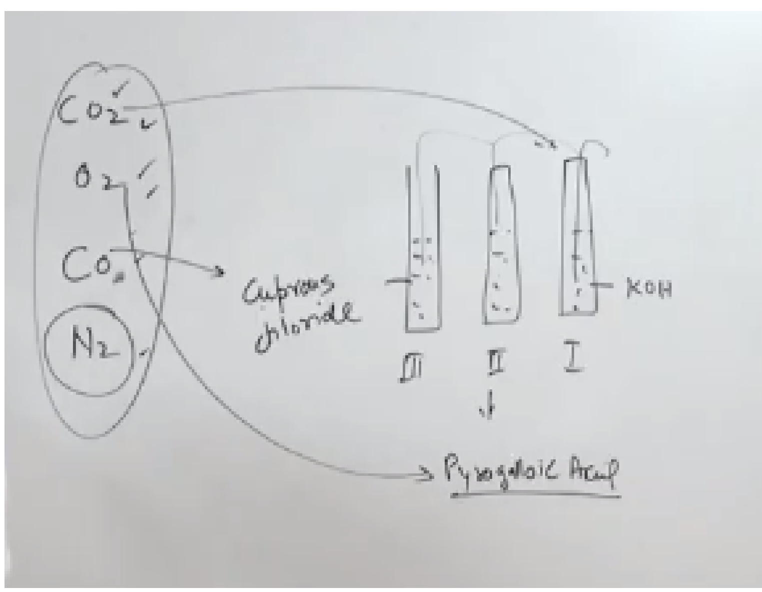

In flue gas analysis mainly the amount of carbon dioxide oxygen and carbon monoxide and nitrogen is by balance right.

Three flask are taken three flask I am just giving the schematic three flask 1, 2 and 3 they are filled up to certain level with the liquids. First is KOH potassium hydroxide right this is to observe carbon di oxide now the second one is having Pyrogallic acid Pyrogallic acid just to observe oxygen. So the pyrogallic acid is to observe oxygen so the pyro gallic acid observe the oxygen and the third one is having cuprous chloride and the cuprous chloride consumes the carbon mono oxide.

So this is for oxygen pyrogallic acid carbon monoxide and carbon dioxide and by balance figure nitrogen we take fix amount flue gases let us take the same of hundred (()) (03:05) of flue gases and that amount of flue gases is past first past KOH and amount of flue gases that the volume of flue gases are observed by the KOH is noted than it goes to this pyrogallic acid tube and then third one is cuprous chloride tube and remaining is nitrogen that is how we get the percentage of CO2, O2, CO and nitrogen.

Now with the help of this analysis we can easily find how much air is used for burning the fuel right.

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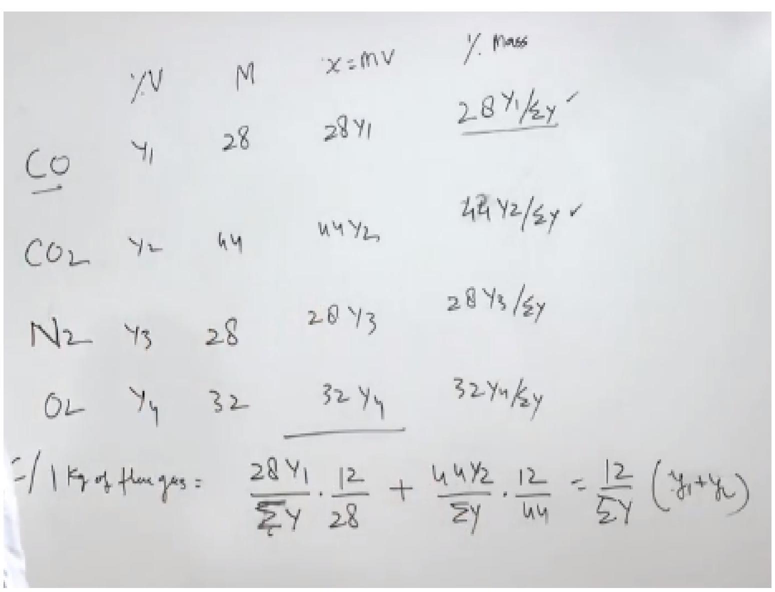

So for this will start with prepare a table suppose in the flue gas analysis CO, CO2 and 2 and O2 right. The volumetric fraction is X1, X2, X3 and X4 this is volumetric fraction 5% is CO 30 % is CO2 5 % 37, 80 % something like that. So they are figure now we have taken a variable percentage volume right. Molecular mass for CO it is 28 for CO2 it is 44 for nitrogen is 28 again and for oxygen is 30 right.

Now we calculate another X or this is let us not get confuse with the X and Y so we will take Y1, Y2, Y3 and Y4 right. So this is M and X = MV, M and this is V this will give you 28, Y1, 44 Y2, 28 Y3, 32 Y4. Again we are working on the same principle 1 kilo will occupy a fix volume 32.4 right.

Now this is composition ratio in percentage of mass so in order to find sorry this is the composition of gas it consist 28 Y1 KG of CO 44 Y2 KG of CO2 28 Y2 KG of nitrogen 32 KG of oxygen. Now again in order to find percentage here percentage by mass we will take we will take sigma Y right. And 28 Y1 by sigma Y 44 Y2 by sigma Y 28 Y3 by sigma Y and 34 Y by sigma Y right.

So this is percentage by mass so in exhaust gases per KG this divide by 100 is KG of carbon mono oxide this divided by this divide by this gives in a value of carbon di oxide accordingly nitrogen also be this can also be taken. Now here let us take one KG of flue gas will consist of how much KG of carbon monoxide let us this one right.

And how much KG of mono oxide this much right so carbon per KG of flue gases now we have to find carbon per KG of flue gases the philosophy is now we will calculate how much carbon is there per KG of flue gases and per KG of fuel carbon contain here suppose carbon contain is .86 KG right the per KG of flue gases how much carbon is there and with that we will find how much flue gases is there what is the mass of flue gases.

So carbon per KG of flue gases carbon per KG of flue gases is going to be 28 Y1 by Sigma Y multiplied by 12 by 28 will be cancelled out. Similarly for carbon di oxide it is going to be 44 Y2 by Sigma Y multiplied by 12 Y 44 this is the amount of carbon available in 1 KG of flue gases right.

And we add this two then we will get 12 by sigma Y X1 + sorry Y1 + Y2 because this 28 cancelled out this 44, 44 will be cancelled out. So we will be getting twelve by sigma Y 1 + Y2 this is per KG suppose there is N KG of flue gases mass of the flue gases is N KG.

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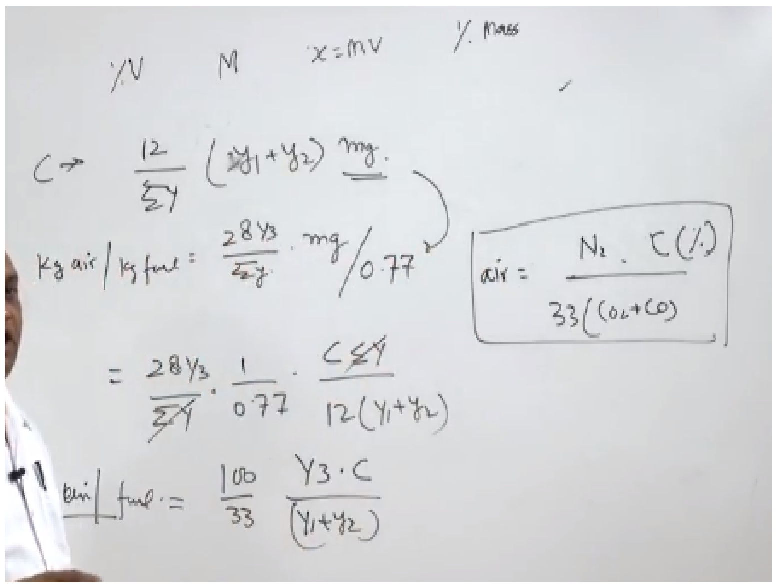

So the carbon is going to be 12 divided by sigma Y Y1 + Y2 mass of the flue gases. Now this is Y1 and Y2 is we have take from volume remember we should not forget this is from the volume only percentage volume of carbon monoxide and percentage volume of carbon dioxide in flue gases right that is one thing. Now regarding nitrogen is 28 Y3 by sigma Y nitrogen does not take part in combustion so it was whatever the combustion is there in the air it has come into the flue gases.

So KG of air per KG of fuel is 28 Y3 by sigma Y multiplied by mass of the flue gases is it clear this is the percentage of nitrogen can flue gases per KG of flue gases or per KG of flue gases this is the nitrogen and it is multiplied by MG here right and this further because we have to find here so this is multiple divided by .77 then we will get air only otherwise it was nitrogen only.

So this the amount of nitrogen this is nitrogen per mass section of nitrogen per KG of flue gases multiplied by the mass of flue gases divided by .77 we get KG of air per KG of fuel right. Now from here the value of MV can be manipulated from this equation to this equation that will give 28 Y3 divide by sigma Y multiplied divide 1 by 0.77.

MG will be C sigma Y divide by 12 Y1 + Y2, C multiplied by sigma Y divide by twelve Y1 + Y2 right. So sigma Y sigma Y will be cancelled out and twenty eight divided by .77, .12 yes this is 28 divided by .77 divided by 12 = it is 100 by 33 right. So we will take 100 by 33 Y3 divided by Y1 + Y2 multiplied by C.

It means now from here this KG of air per KG of air per KG of fuel we are burning one KG of coal or fuel this much of KG of air will be required to per 1 KG of fuel. That is hundred by 33 volume of nitrogen in exhaust gases we have taken some sentence so percentage volume of nitrogen and exhaust gases percentage volume of carbon monoxide in exhaust gases percentage volume of carbon oxide like exhaust gases and amount of carbon 1 Kg of fuel.

Or we can write it like this air is equal to amount of air which is N2 percentage of volume we will write N2 divided by 33 CO2 + CO and carbon percentage wise because this hundred will multiplies by to C will be per hundred this is carbon contain per KG. So it suppose it is 86 % of carbon so C is going to be 86 so this is the formula to find how much air is used for burning the fuel.

So directly from the formula we can find how the how much is used for burning the fuel air may be access in amount this is also possible that we supply 20, 30 or 50 % and excess air and in the product of combustion carbon dioxide is there carbon monoxide is there that is also possible right. So we will take one numerical to understand this this numerical states during the boiler trial following data were obtained.

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Numerical #1

During the boiler trial following data were obtained:

Coal analysis dry: C=85.5%, H=4.5%, ash = 10%, GCV of dry coal 35 MJ/kg; moisture content 1.8%; coal consumption 1450 kg/h; Boiler room temperature 25 °C; feed water temperature 55 °C; steam pressure 1.2 MPa, steam temperature 250 °C; steam raised 12500 kg/h; Analysis of dry flue gases by volume of gases: CO_2 =9.5%, O_2 =11.0%, N_2= 79.5%. The temperature of gases in the uptake was 300 °C. Mean specific of dry gases 1.005 kJ/kg.

Prepare a complete balance sheet per kg of dry coal.

So coal analysis was done carbon was 85.5 % hydrogen 4.5 % as 10 % gross calorific value of dry coal is 35 mega joules per KG. Moisture it has moistures 1.8 % coal consumption is 1450 KG per hour. Boiler room temperature is 25 degree centigrade feed water temperature is 55 degree centigrade steam pressure 1.2 mega pascal is steam temperature pressure 25 degree centigrade steam raised 12500 KG per hour.

So how much steam is raised per KG of coal we can easily find out coal combustion is it is given 1450. So how much steam is raised per KG of coal we can find out analysis dry flue gases by volume of gases this is by done by offset operators as I explained earlier. So in exhaust gases carbon dioxide is 9.5 % oxygen is 11 % nitrogen is 79.5 % and there is no carbon monoxide.

The temperature of gases in the up take was three 100 degree centigrade mean specific dry gases mean specific heat also this is mean specific heat of dry gases is 1.005 kilo joules pet KG kelvin right. So now we have to prepare complete balance sheet of heat transmission. So first of all we will find how much coal is spent or per KG of coal how much steam is raised.

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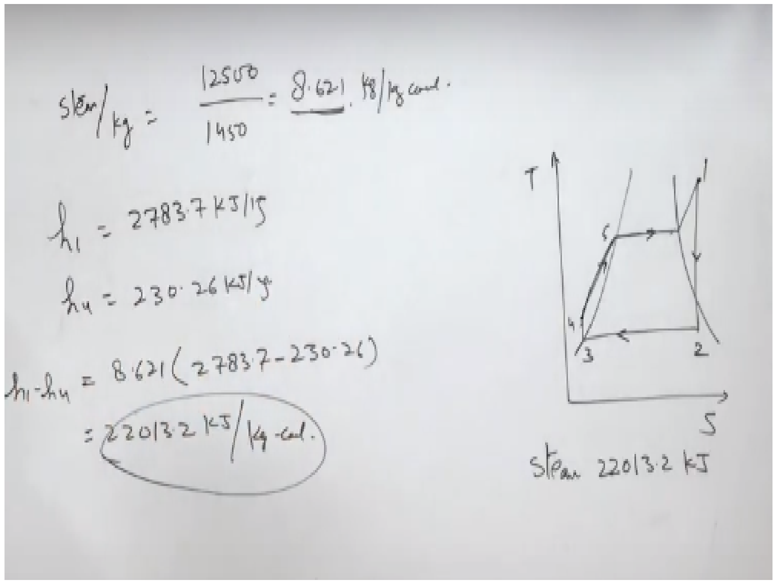

So steam raised per KG of coal steam per KG of coal is equal to 12500 divided by 1450 and that is going to be = 8.621 KG per KG coal. So perk when you are burning one KG of coal this much amount of steam is liberated. Now much heat is carried away by steam this we can again look at the ranking cycle at temperature entropy diagram the stem here is superheated.

So 1, 2, 3, 4, 5 so steam is superheated so we have to find the value of H1 feed water temperature will be at H4 and difference two will be will give us the amount of heat transmission to the feed water is boiler.

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kPa	deg. C	h_f	h_{fg}	h_g
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
55	15.762	230.26	2369.84	2600.1

		100 kPa		
C	v	u	h	s
250	2.4062	2733.9	2974.5	8.0346
300	2.6388	2810.6	3074.5	8.2172
350	2.871	2888.7	3175.8	8.3866

So for superheated steam we have superheated steam table at it is saturated it is saturated ok no problem we have the enthalpy at state one H1 from steam table we can take 2783.7 kilo joules per KG H4 can be calculated from the steam table 230.26 kilo joules per KG and this supplied H1 - H4 is going to be 8.21 multiplied by 2783.7 -230.26 and that is going to be 22013.2 kilo joules per KG sorry this is kilo joules per KG coal.

Because per KG of coal this much of steam is liberated so whatever heating value one KG of coal is having this much of heat is going out of steam you can note it down also somewhere. So steam is taking away 22013.2 kilo joules that is per KG of coal. Now air supplied how much air is supplied to for burning the fuel. Earlier we have already done a derivation using that that derivation that formula we can easily find how much air is supplied.

So air supplied is volume of nitrogen in volumetric analysis divide by 33 volume of CO2 + volume of CO percentage of carbon right. Now volume of nitrogen how much volume of nitrogen is there it is 79.5 divided by 33 volume of CO2 9.5 + 0 multiplied by carbon 85.5 and this will give us the amount of air supplied and that is coming 21.68 KG per KG of coal fuel.

So 21.68 mass of the air is 21.68 KG so this is the mass of air which is circulated but actual mass of air for burning the coal is how much. This is the mass of air supplied to the boiler but how much air has been used.

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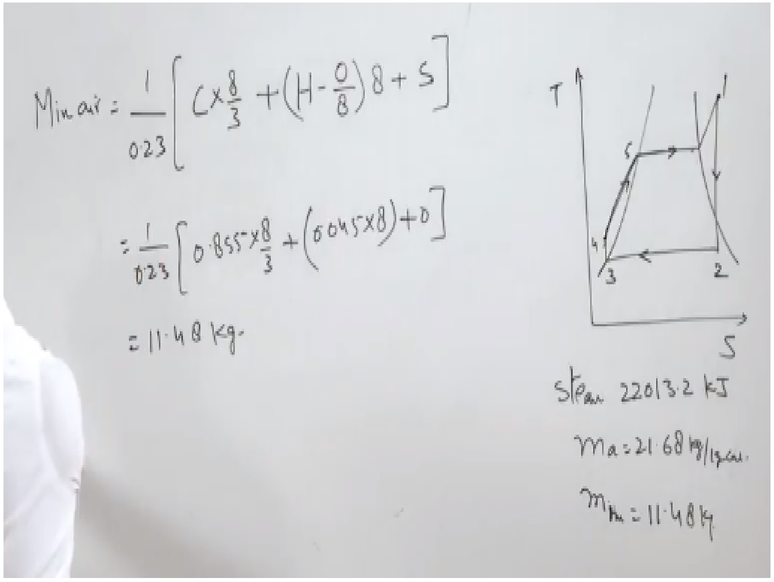

In order to find that minimum air is equal to for burning carbon we need 8 by 3 right for burning hydrogen H - O by 8 multiplied by for sulfur 1 KG of air as though it is only S though it S only S if sulfur is there sulfur is not there. So simply minimum calculating minimum air now this is minimum oxygen not air so in order to find minimum air has to be divided by 0.23 then we will get minimum air this is minimum oxygen.

So 1 by 0.23 now here 0.25 into 8 by 3 + 0.045 into 8 oxygen is not there ok and S is also 0 an minimum air is 11.48 KG. So mass of the air supplied is 20.68 so mass of the minimum mass of the air is 11.48 KG and there is excess air.

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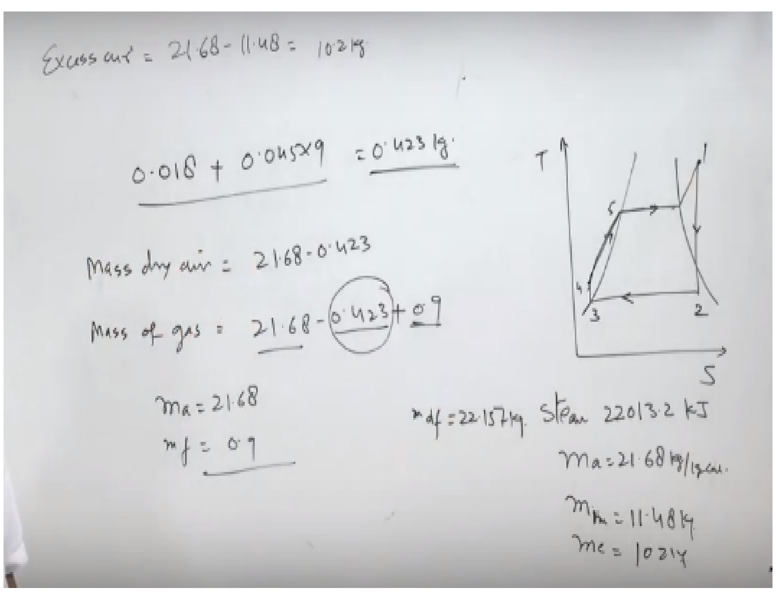

And excess air is equal to this 21.68 - 11.48 = 10.2 KG per KG of mole. We are just calculating everything per KG of coal because in balance sheet we have to give in terms of percentage. So if we find all the values per KG of coal that will serve the purpose.

Now mass of water vapor percentage of hydrogen is 4.5 % moisture content is 1.8 % so this moisture is taking heat from the coal and the liquid is moisture converted into high temperature vapor and it going with the flue gases. So moisture is 0.018 + hydrogen 0.045 into nine this is the total amount of water present in the flue gases because moisture is also there 1.8 %.

So now this plus this will give 0.423 KG of water in per KG of sorry 0.423 KG of water going with the flue gases when we are burning 1 KG of fuel. So mass of the dry air will be difference of this sorry mass of the dry air will be difference of yes this 21.68 – 0.423 + coal which is burnt it is also come into the flue gases right.

So this is the mass of the dry air and mass of gas flue gases dry gases is 20.68 – 0.423 + 0.9 say air which is burn suppose this is mass of weight 21.68 we can write this way also mass of the air = 21.68 mass of the fuel is 0.9 is 85.5 %, 4.5 % it is 90 % 0.9.

So we can add this two right and then remove 4.3 so we will get the mass of the dry flue gases. So the mass of the dry flue gases dry flue gases 22.157 KG so now we have calculated mass of the dry flue gases mass of the access here mass of the air and minimum mass of air which is required and access here also mass of the access air is 10.2 KG right.

So certain amount air is supplied for the burning of fuel so part of the air as been used for burning the fuel access air is this much 10.2 KG. Air as come to flue gases product of combustion have come to the flue gases water vapor as come to the flue gases now if you want to have mass of the dry flue gases in that case we will remove this water content and in the air we will add mass of the fuel which is coming with the flue gases.

Because ash will not come with the flue gases the ash will be certainly the grate itself in the pit below the grate. Now after this this is the mass of the flue gases now mass of if we remove the mass of air excess air mass of this is mass of dry flue gases if out of this five remove the mass of the excess air will be get mass of the combustion products. Flue gases are consisting of the combustion products excess air and everything.

So mass of the dry flue gases if I remove excess air will be getting mass of the combustion products.

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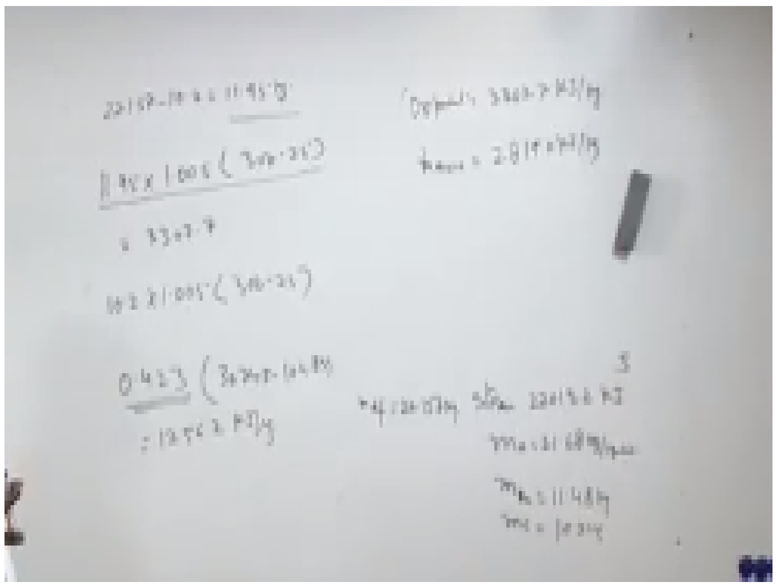

So mass of the combustion products is 22.157 – 10.2 it is coming 11.95 KG. Now heat because this specific heat is given 1.005 here it is equal to the specific heat of the air sometimes it is different. So I have taken a generalize case here you can take both and I mean both the combustion product and air together.

But suppose the specific heat of dry gases is one point instead of 1.005 it is 1.030 in that case the scenario it is going to be different. So now this is M 11.95 CP 1.005 delta T is 300 - 25 so this is the amount of heat which is going with dry product of combustion right.

And that is here it is coming out to be 3302.7 we will write some where here heat with the dry product is equal to 3302.7 kilo joules per KG. Now heat and access air now access air is 10.2. So 10.2 into 1.005, 3000 - 25 here because CP is same for both the cases but again for the access here it is coming access.

Access here it is coming 281910 kilo joules per KG now vapors we have vapors also. The mass of the vapor is 0.423 right and the enthalpy of vapor is also changing it is I mean enthalpy at 300 this is 300 outgoing 300 degree centigrade. So enthalpy of water atmospheric pressure water is atmospheric temperature is 25 enthalpy of 300 - enthalpy of 25.

So it is coming around 3074.5 -1.4.83 and it is 12506.2 kilo joules per KG. So now we have everything now we have information about how much heat is going with the first of all let us see how much heat is supplied in the boiler.

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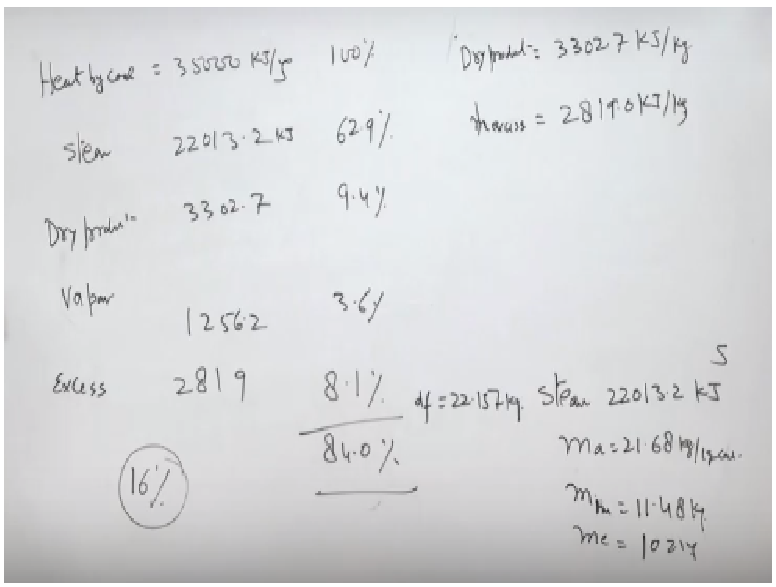

Heat by coal = 35,000 kilo joule per KG that is 100% heat right now steam where it is going it is going to steam 22013.2 kilo joules it is kilojoules right per KG right and it is coming 62.9 %. So 62.9 % efficiency of the boiler also 62.9 % now heat in dry product is 3302.7 it is 9.4 %.

Heat in vapor just now we calculated one 256.2 and that is 3.6 %. Heat in excess air that is also heat in excess air is 2811 and that is 84 % and that is coming around 84.0 % right. Now this is 100% so 60 % of heat is unaccounted so 60 % of heat is going to the surroundings in the form of radiations right in the form of conduction and in other forms.

So that is how the boiler trial is taken and the balance sheet of boiler is prepared from the next class we will start with the nozzles.