Steam and Gas Power Systems
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Module No # 03
Lecture No # 15
Combustion of Fuel (Problem Solving)

Hello I welcome you all in this course of steam and gas power systems today we will solve problem related with the fuel gas analysis.

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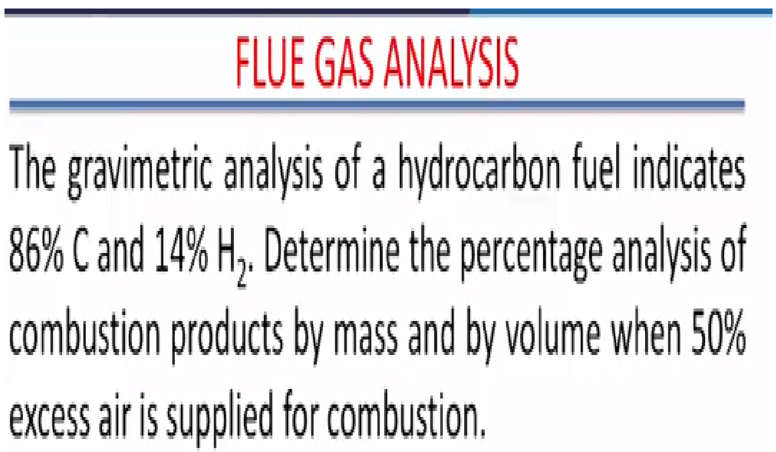

In this problem gravity analysis of hydrocarbon fuel indicates 80 % of carbon and 14 % of hydrogen. Determine the percentage analysis of combustion products by mass and by volume what is the percentage of mass percentage of percentage by mass what is percentage by volume is there carbon dioxide and in water vapor and maybe carbon monoxide.

And when the 50 % of accessory supplied for combustion when 50 % excess air is supplied it is assumed that there is no formation of carbon monoxide it is only carbon dioxide.

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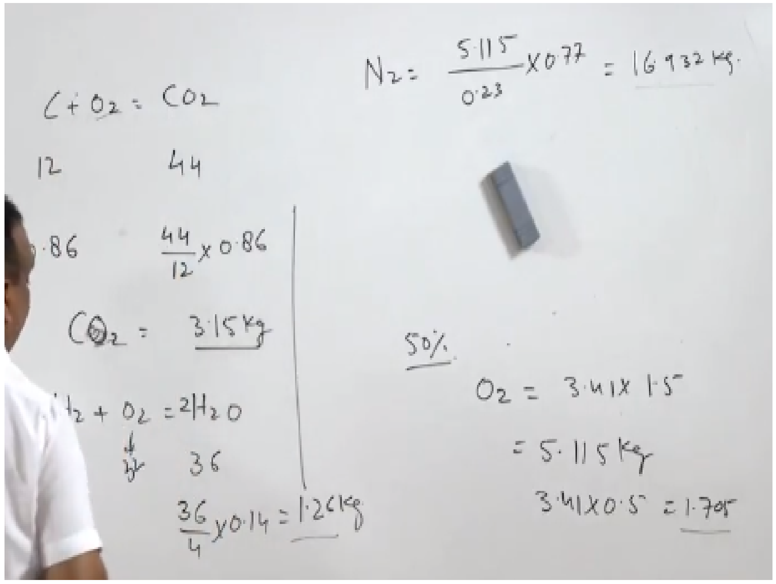

So when carbon dioxide carbon is oxidized to carbon dioxide C + O2 = CO2. So 1 KG of 1 mole means 12 KG of carbon 1 kilo mole 12 KG of carbon will form 44 KG of carbon dioxide right. So from this we have per KG we have 0.86 KG of carbon will form 44 by 12 multiplied by 0.86 and that will give 3.15 KG of carbon dioxide by mass.

Regarding hydrogen H2 + O2 = H2% will give 36 by 4 into 0.14 and that is going to be = 1.26 KG of H2. Now there is 50 % of excess air we have supplied first of all we have to find the air how much air is required and then we will calculate how much air excess in KG how much excess air is there.

So total oxygen required is how much this three point sorry total oxygen required yes so this is product of combustion now oxygen required for burning 12 KG of carbon 30 KG of oxygen is required. So for burning of 0.86 of carbon the oxygen required will be 32 by 12 into 0.86 right. This is for carbon for hydrogen similarly for burning of 4 KG of hydrogen 32 KG of oxygen is required.

So for 4 KG 32 KG is required and for 0.14 KG 32 by 4 into 0.14 if we take some of this and this it comes out to be 3.14 KG of Oxygen this is about the do not get confuse with the product of combustion. This is the product of combustion and this is oxygen required for burning carbon and hydrogen. Now this 3.41 has 50 % access here it means the excess air is 3.41 into 1.5.

So total air is five point so total air is this is oxygen right now we have using 50% excess air. So 50 % excess oxygen this is not excess here this is excess oxygen so oxygen is 3.41 into 1.5 this is total oxygen. So total oxygen is 5.115 KG now this is the total oxygen total oxygen divided by 0.23 will give you the total here right.

Now this is total oxygen and what about excess oxygen is 3.41 into 0.5 and this will give around 3.41, 1.705 now the burnt gases are also having nitrogen it is written here determine the percentage analysis of combustion products by mass and by volume.

So the combustion the nitrogen also go with the flue gases in order to find the quantity of nitrogen how much nitrogen is going with the flue gases. So this is the quantity of oxygen 5.115 quantity of air divided by 0.23 and amount of nitrogen is multiplies by 0.77. This will give the amount of nitrogen which is coming out to be 16.932 KG.

So product of combustion we have carbon dioxide 3.15 KG water 1.26 KG nitrogen 16.93 KG. Oxygen how much oxygen 1.705 KG this is also going so this is the nitrogen out of nitrogen which is going with the exhaust gases this is all oxygen going with the exhaust gases because oxygen is supplied with the gases 50 % access. This is water going with the outgoing gases and this is the carbon dioxide going with the outgoing gases.

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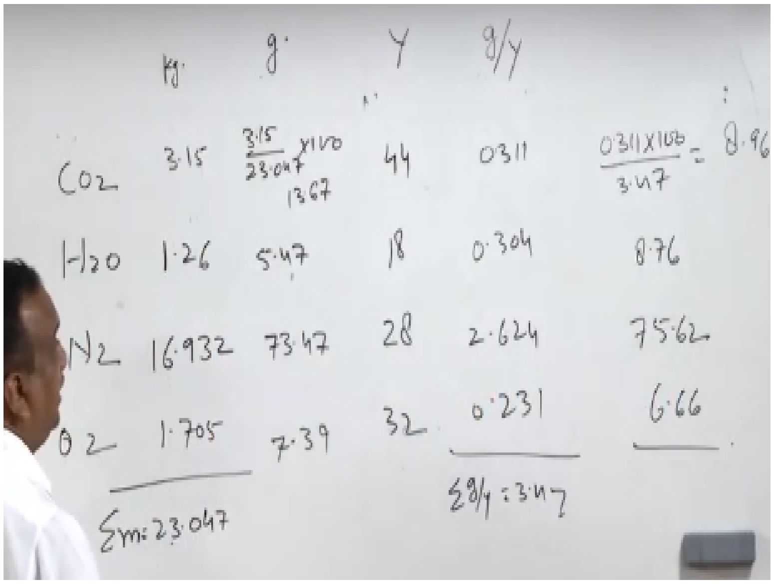

So we will make a table so it is CO2 H2O nitrogen oxygen CO2 is 3.15 this water is 1.26 nitrogen is 16.93 and water is 1.705. There all one KGs so this is the composition of exhaust gases so what we have done we have taken from the composition of carbon and hydrogen we have take we have calculated how much carbon dioxide what how much water will be produced.

How much oxygen will be used for burning the carbon and hydrogen oxidizing for hydrogen and carbon and that oxygen is 50 % gases because air is 50 access through oxygen is also 50 %. So we have calculated the oxygen 50 % oxygen is going with the flue gases and with the quantity of oxygen gases we have found the quantity of nitrogen okay. Now after this what we have to do determine the percent analysis of combustion product by mass.

So take some of this okay some of all this is 23.047 this is the sum and then by percentage you can always take 3.15 divided by this. So 3.15 divided by this multiplied by 100 so 3.15 divided by 23.047 multiplied by 100. Accordingly we will do for this hydrogen sorry this water nitrogen and oxygen as well and the values are this is 5.47, 73.47, 7.39 and this will be 13.67 okay.

So this is by mass this is G right now volume now we have to convert mass into volume if you remember if we take 1 kilo mole of any gas it will occupy 22.4 meter cube of volume or 1 mole will occupy 22.4 liters. So volume occupied by one mole is same for all the gases right and how will get the mole fraction just mass divided by the molecular weight will get the mole friction.

So molecular weight let us take Y is air for 44 this is H2O it is 18 nitrogen 28 oxygen 32. Now here we can take the mole friction so when we take the mole friction then G is divided by Y. So let us take G by Y the mole friction is 0.311, 0.304, 2.624, 0.231. So here we are getting mole friction will be percentage of volume because 1 mole is of for all is occupying the same volume.

So here again this sigma G by Y is taken that is 3.47 and again taking percentage this multiplied by this divided by sigma multiplied by 100. So 0.311 multiplies by 100 divide by 3.47 will give the volumetric consideration of carbon dioxide that is 8.96 similarly for water is 80.76 for nitrogen 75.62 for oxygen it is coming for 6.66 right.

This is how the percentage by mass we can convert into percentage by volume because this is very important. When we deal with the combustion of the fuel when the flue side unborn flue side it is always in KG's. But when we do the gas analysis find composition of the gas their given in percentage in volume. So this conversion of the person who is dealing with the combustion has to be very comfortable with this conversion.

Conversion in from percentage of mass to percentage of volume and for conversion from percentage of volume to the percentage of mass. Now in this problem it is required the calculate the proportion of heat or fuel carried away by the flue gases for the following data. Coal with calorific value of 30 mega joules per KG.

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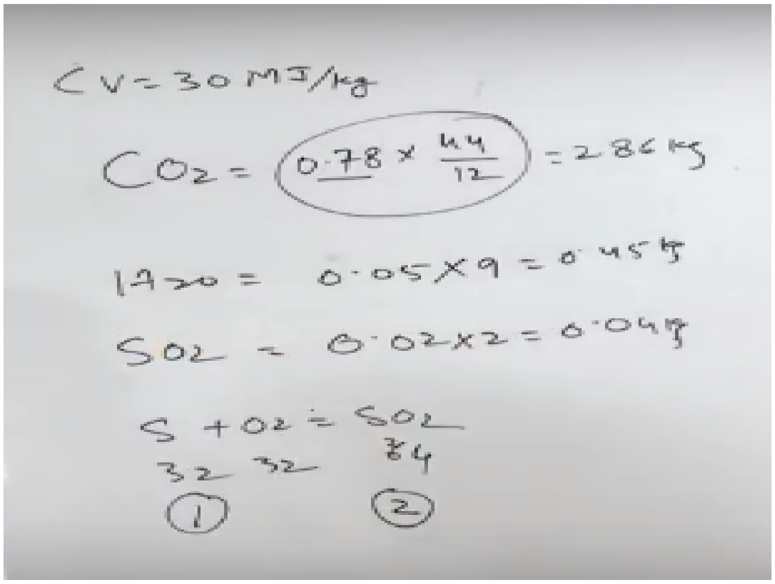

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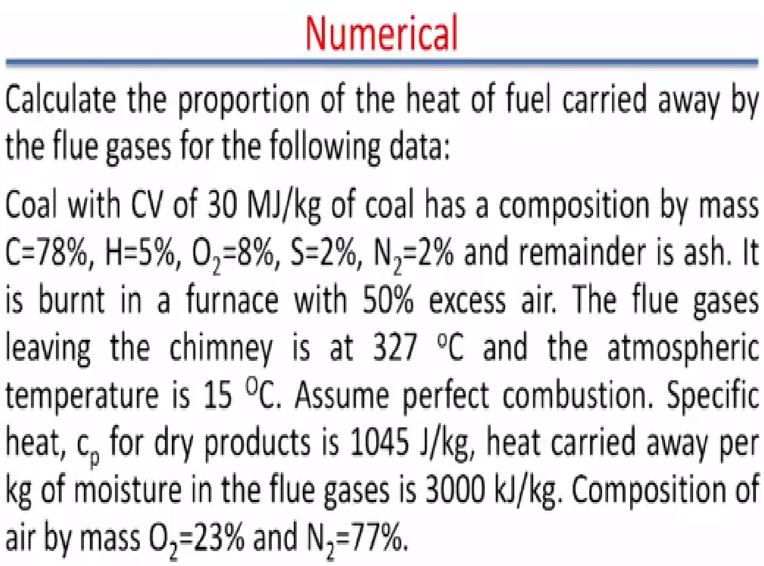

So the calorific value of the coal is 30 mega joules per KG it as composition carbon 70 % hydrogen 5 % oxygen 8 % sulfur 2 % and it has nitrogen also which is 2 % remaining is ash it is burned in a furnace with 50 % of excess air the flue gases living the chimney are at 327 degree centigrade and atmospheric temperature is 15 degree centigrade.

So the temperature of the gases is increased from 16 degree centigrade to 327 degree centigrade. Assume perfect combustion it means all carbon is converted into carbon di oxide. Specific heat for dry products is 1045 that is carbon di oxide sulfur di oxide right heat carried away per KG of moisture in the flue gases 3000 kilo joules per KG composition of air is also give as 33% and 77%.

So first of all we wills start with the product of combustion now the CO_2 how much CO_2 has been formed. So CO_2 is 0.78 multiplies by 44 by 12 as we did earlier $C + O_2 = CO_2$ this is 12 and this is 44 for burning 12 KG of carbon we require 44 KG of sorry we produce 44 KG of carbon dioxide. 32 KG of air is required and 44 KG of carbon di oxide is produced.

So for burning 0.7 to 8 KG of carbon di oxide so carbon 0.78 per KG of carbon this much carbon di oxide is to be produced and that is equal to 2.86 KG. Similarly for water for H_2O 0.05 that is 5 % of hydrogen is there and water will be produced multiplied by 9 that is 0.45 KG. Sulfur di oxide $S + O_2 = + O_2$ 32 and this is 64 and this is 32.

So one KG two KG of sulfur di oxide is produced with 1 KG of sulfur here the sulfur is 0.02 multiplied by 2 = 0.04 KG. So this are the product of combustion we are burning per KG of fuel per KG of fuel is having .78 carbon which is producing this much carbon di oxide 5 % of hydrogen which is producing this much of water vapor sulfur di oxide 2 % which is producing this much of sorry sulfur is 0.2 % which is producing 0.04 KG of sulfur di oxide.

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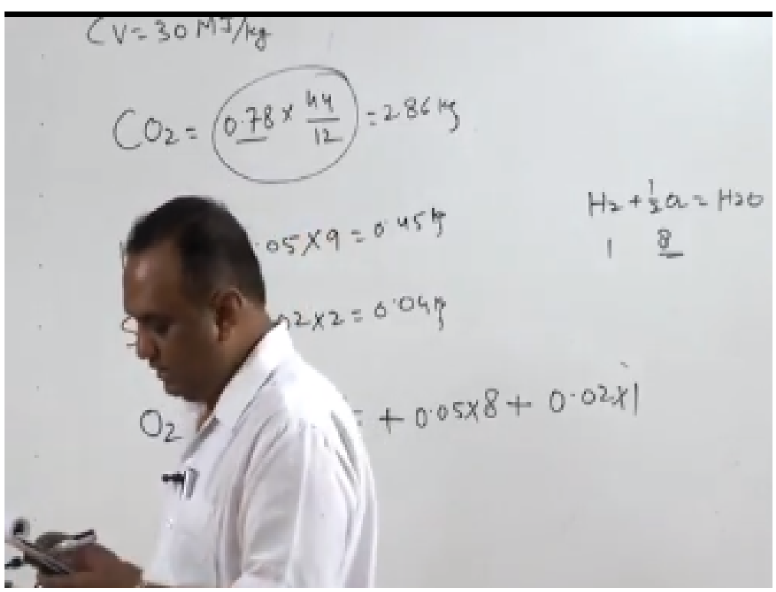

So how much oxygen will be required now oxygen required will be oxygen alright here for carbon 0.78 multiplies by 32 by 12 because oxygen is 31 + O2 = CO2 so this is 32 by 12 multiplied by 0.78 + 0.05 multiplied by 8 as in the case of hydrogen.

H2 + half = H2O so 1 KG so this will require 8 KG of oxygen another is sulfur di oxide which will take 1 KG of sorry 0.02 KG of oxygen. So the total oxygen required is 2.5 KG here also excess of air is required I mean 50 % of air is supplied.

So oxygen is will be there in combustion of products nitrogen will also be there in the combustion product and that nitrogen will also contain nitrogen in the fuel also this 2 % of the fuel of nitrogen which is already available in the fuel. So that has to added in the nitrogen so 50 % excess here so this is air required 50 % excess air.

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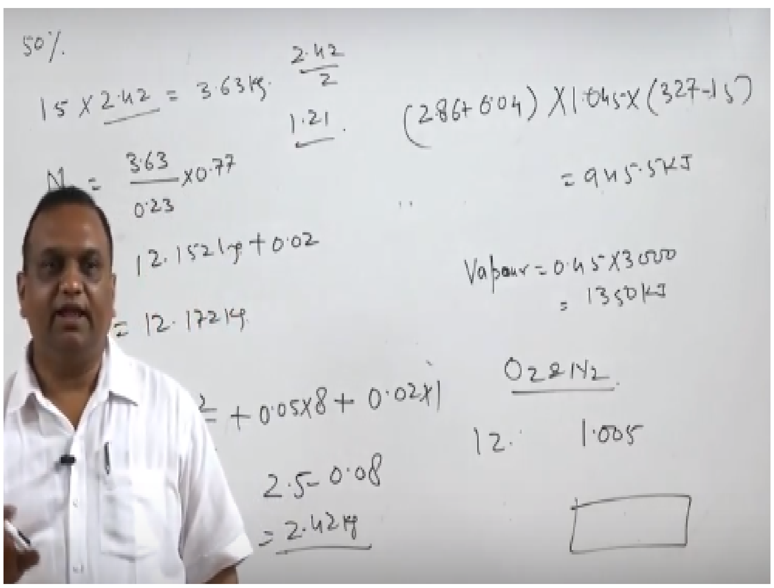

So 50% excess air is so this is air required so 50 % excess air it means 1.5 just a minute 2.5 KG of oxygen is available in fuel also. So actual oxygen is not outside oxygen is required 2.5 KG but oxygen from air supplied is required as 2.5 – 2.42 KG. This oxygen will come from air now 50 % of this is actually supplied for two point and this will be equal to 3.63 KG.

Nitrogen if you want to find nitrogen how much nitrogen is supplied it is 3.63 divided by 0.23 multiplied by 0.77. This will give how much nitrogen supplied that is coming out 12.15 to KG nitrogen is coming from here also. So that will also be added here plus 0.02 kg will also be added here and that will be the final amount of nitrogen in the flue gases.

Now we have all the products of combustion right now heat carried away by the dry products what are the dry products carbon di oxide sulfur di oxide right. Nitrogen say nitrogen is a part of air so specific heat for nitrogen and oxygen will take as 1.005 this is specific heat for dry products means carbon di oxide and sulfur di oxide mean. So we will take only carbon di oxide and sulfur di oxide and CP 1.0 how much .045 into 357 - 15 that is 925. kilo joules per KG.

Heat carried away by the vapor how much vapor is formed how much nitrogen is form hydrogen is 0.45. So vapor heat carried away by the vapor 0.45 into three thousand = 35 kilo joules per KG sorry kilo joules per KG it is kilo joules this is also kilo joules right. Now heat carried away by nitrogen and oxygen heat carried away from nitrogen and oxygen is 12.172 right plus what is the value of oxygen is excess of oxygen is 1.212, 42.42 divided by 2.

It is 1.2 one this is excess of oxygen this will and this mass MCP here will be 1.005 and delta T. All this values will be added and then we will get the final heat which is going with the flue gases.

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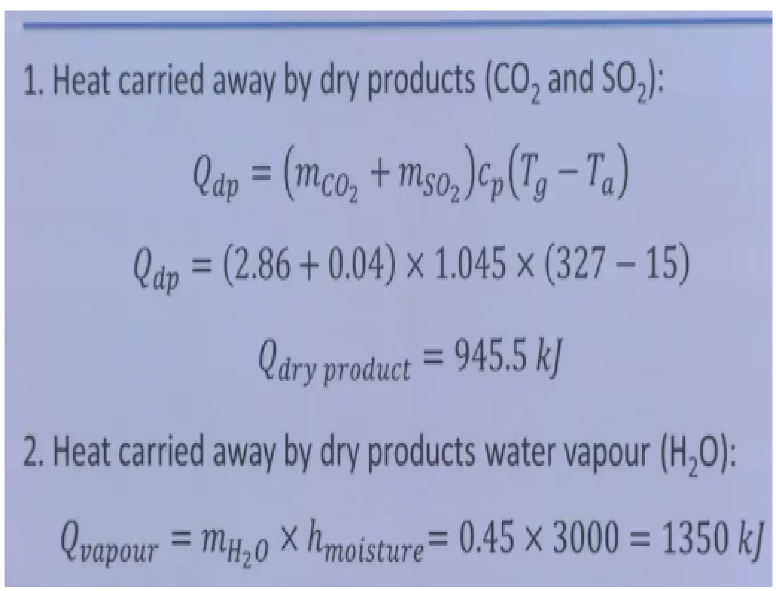

In the nutshell we will find the heat carries away by the flue gases the flue gases consist of carbon di oxide sulfur di oxide nitrogen oxygen and water vapor. So heat carried away by the carbon di oxide and sulfur di oxide can be calculated by using this equation Q = MCP delta P. Where M is the sum of the mass of the carbon di oxide and mass of the sulfur di oxide for both of them the specific heat is 1.045 kilo joules per KG can be.

TG is 327 degree centigrade that is the temperature of the flue gases and TA is the temperature of ambience or ambience temperature and this case the heat transfer of dry product as 900 and 45.5 kilo joules. Second is heat carried away by water vapor that is mass of the water vapor multiplied by enthalpy of moisture?

Enthalpy of moisture is given in the statement of the problem and mass of the hydrogen that is water vapor is 0.45 and this heat taken away by the vapor is turns out to be one thousand three hundred and 50 kilo joules.

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3. Heat carried away by oxygen and nitrogen (O_2 and N_2):

$$Q_{ON} = (m_{O_2} + m_{N_2}) c_p (T_g - T_a)$$

$$Q_{ON} = (12.152 + 1.21) \times 1.005 \times (327 - 15)$$

$$Q_{ON} = 4189.8\ kJ$$

Total Heat carried away by flue gases

$$Q_f = 945.5 + 1350 + 4189.8 = 6486.3\ kJ$$

$$\text{Proportion of CV in flue gases} = \frac{6486.3}{30000} \times 100 = 21.6\%$$

Now thirdly we calculated the heat carried away by oxygen and nitrogen and both of them are having the specific heat of 1.005 kilo joules per KG. So we are taken the mass of the oxygen and mass of the nitrogen multiplied by the specific heat again multiplied by the temperature rise and heat taken away by the oxygen and nitrogen is 4189.8 kilo joules.

The sum of all this these three values is 6486.3 kilo joules. The proposition of calorific value of the fuel which goes with the flue gases so this compression of the calorific value of the fuel which goes to the flue gases is the ratio of heat with the flue gases divided by calorific value of fuel multiply by 100 will give the percentage of proportion of calorific value going with the flue gases and that is 21.6 % right that is all for today next time we will start with boiler trial.