Steam and Gas Power Systems

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

Module No # 03
Lecture No # 14
Combustion of Fuel

Hello I welcome you all in this course on steam and gas power system today we will discuss about the combustion of fuel. Now in boilers solid and liquid fuel is used and in all the cases gases fuel is also used in boilers and when we burn the fuel the immediately the fuel air ratio is comes into the picture.

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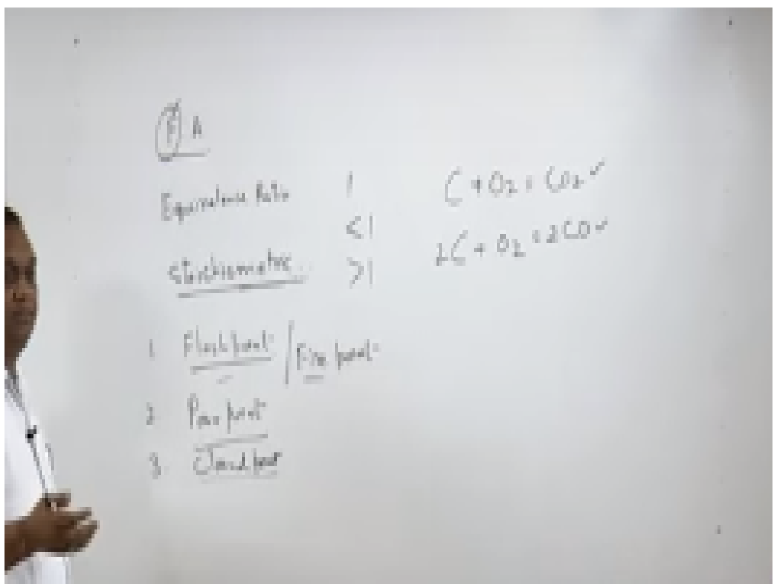

Fuel air ratio denoted how much air for burning the fuel right and there is a term equivalence ratio. If air is just sufficient to burn the fuel or it stoichiometric ratio stoichiometric means air is just sufficient to burn the fuel. So there is no excess of the fuel there is sorry there is no excess of the air and there is no scarcity of the air right.

So when stoichiometric ratio is maintained then equivalence ratio is one but access when the access air is supplied then equivalence ratio is less than one may be .9 and when the excess of the fuel is there in that case equivalence ratio is greater than one may be 1.05 or 1.1 or 1.2 when access of fuel is there is a phenomena of incomplete combustion. It means carbon is oxidized oxides or oxidized as CO2 while burning and carbon can also be oxidized as carbon monoxide.

But heat liberated in this process much more than heat liberated in this process so there is a it is combustion it is incomplete combustion and due to this incomplete combustion of oxidation of carbon the less of amount of heat is liberated during combustion right. This happens when there is scarcity of oxygen in mixture or the equivalence ratio is greater than one or the mixture is which it is not stoichiometric it is mixture.

Another characteristic of the fuel is flesh point flesh point is the temperature if we start increasing the temperature of the fuel the vapors will be generated and these vapors are volatile vapors. So initial park which burns the vapor combustion is not sustained in flesh point the combustion is not sustained another is fire point. In fire point the combustion is sustained so fire point definitely higher than the flesh point.

Third one is second one sorry this is second one is pour point these are all physical characteristic of the fuel with pour point. The pour point is the minimum temperature at which the fuel is liquid fuel is flowable. So that temperature is known as pour point and there is another term which will find interesting is cloud point.

So cloud point is a temperature at which the solidification of wax present in the fuel takes place so it becomes white surface becomes a little whitish and that is known as cloud point of fuel. Now burning of the boiler as I stated earlier we have solid fuel liquid fuel and we can also use gases fuel as well.

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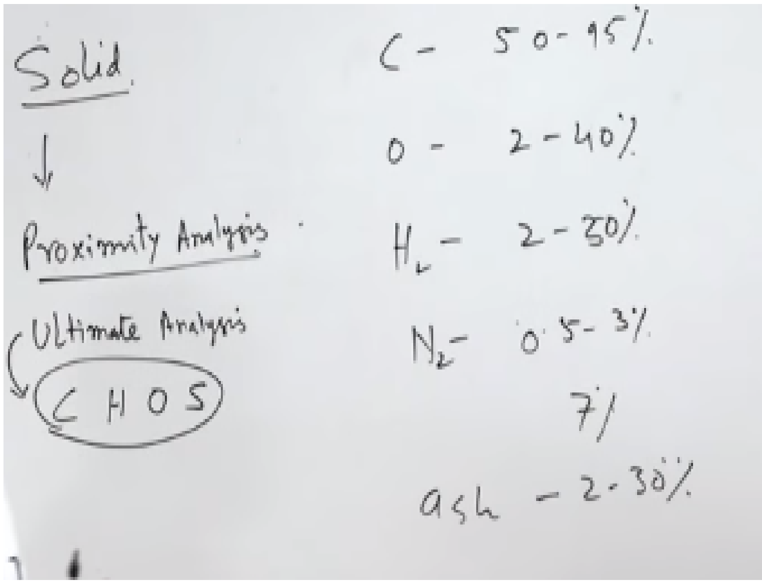

We will start with the solid fuel solid fuel in solid fuel coal is the fuel coal is used as fuel in the boiler and unless has to be because there is a large variety of the coal having difference composition of carbon, hydrogen, oxygen, nitrogen or sulfur. So unless has to be done of the fuel and there are two types of analysis when is proximity analysis and another is ultimate analysis in ultimate analysis everything analyzed.

What is the percentage of carbon? What is the percent of hydrogen? What is the percentage of oxygen? What is the percentage of sulfur? Right how much the amount is ash everything is determined and that is done through ultimate analysis. In proximity analysis normally moisture what is the moisture amount of moisture in the fuel. What is the percentage of volatile material in the fuel what is the percentage of ash in the fuel that is determined through proximity analysis.

Now I will give you certain idea about the figure for example carbon, carbon can vary from 50 to 95 % in coal. If you take anthracite coal it can go up to 95 % oxygen can vary from 2 to 40 %. Coal can have 40% of for example peat coal I will give you the table also it can go up to 40 % hydrogen can also be 2 to 50 % nitrogen 0.5 to 3 %.

Sulfur can also be up to 7 % and ash can go up to 2 to 30 % so there is a wide range. So simply saying we are using coal as fuel is not sufficient we have to specify which quality of coal is being used.

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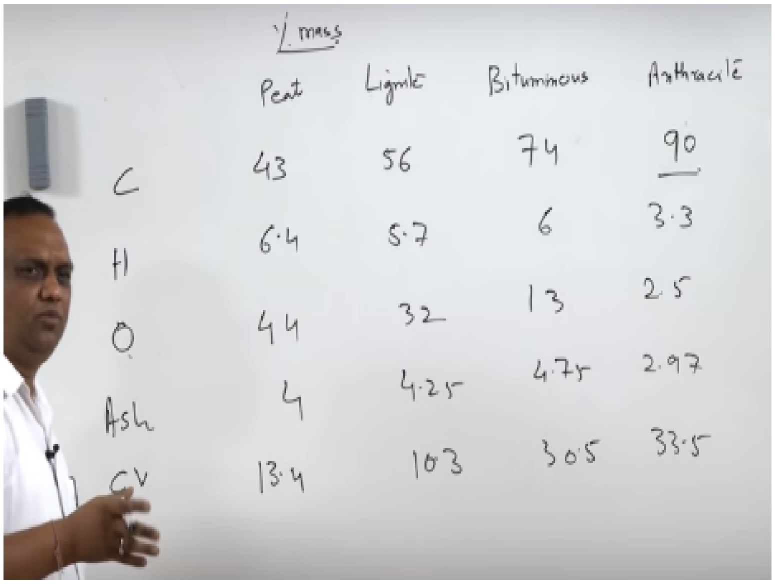

Normally available coal in nature is peat coal another is lignite third one is bituminous and third one is anthracite. Now let us take the case of moisture however moisture is there peat coal as approximately 20% moisture it is in percentage by mass. So all the figure are percentage by mass so it is 20% peat coal can have 20% moisture lignite 15, bituminous 2, anthracite 1.

So it is almost dry normally this goes bituminous and anthracite they are only 2 % or 1 % moisture. Volatile material it is 65 %, 50 %, 25 % and 4 % right. Now let us come to carbon and hydrogen now percentage of carbon in peat coal only 43 % by mass lignite it is 56 % bituminous is 74 % and anthracite is goes up to 90 %.

So it is the highest quality of coal because it is carbon which will get oxidized generates heat majority of heat comes from the carbon right. So it is 90 % in anthracite now hydrogen is 6.4 % peat 5.76 and 3.3 % in anthracite.

So highest hydrogen is peat coal or followed by the lignite coal oxygen in peat coal it goes upto 44 % lignite 32 %, 13 %, 2.5 % peat surprisingly 44 % carbon is 43 % and oxygen this is 44 %. Ash contain it is 4 % 4.25, 4.75 and 2.97.

So this is the best quality of coal ash is also 2.97% calorific value which is of the most concern. Calorific value of this coal is 30.4 mega joules per KG this is 10.3 mega joules per KG 30.5 mega joules per KG and 33.5 mega joules per KG. Approximate this is approximate this is ultimate it can go up to 34 also so it is 33.5 so they are all approximate value.

So here you can make a comparison of the percentage of different components of in different type of course. So definitely then anthracite coal is the quality of the coal which consist on 90% of the carbon and ash contain is also 2.97 %. In addition to this solid fuel liquid fuel is also used in liquid fuel mainly natural gas is used. Natural gas mainly consists of methane and part of ethane also and mainly it is methane which is there in natural gas.

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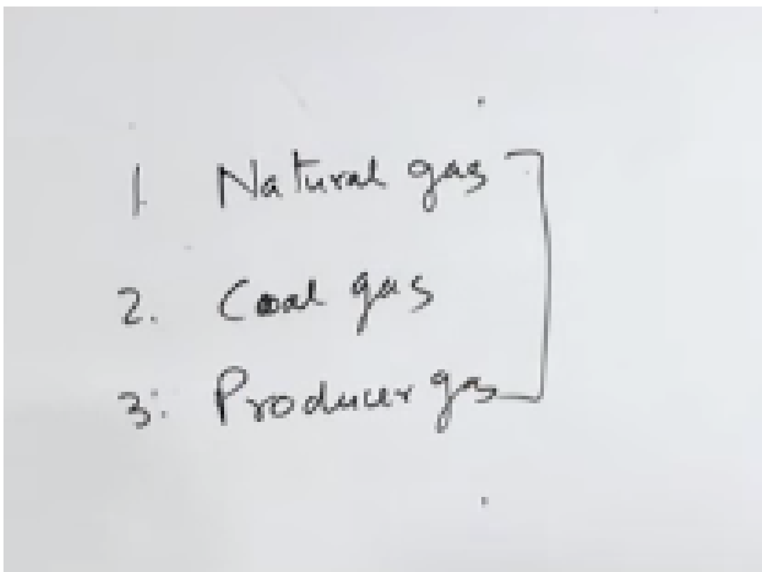

So in gases fuel we can use natural gas and coal gas and three is producer gas so these three gases can be used as a gaseous fuel in boilers. Regarding the liquid fuel paraffin, olefin there are liquid fuel but petroleum can also be used and if you look at the quality of petroleum or the composition of.

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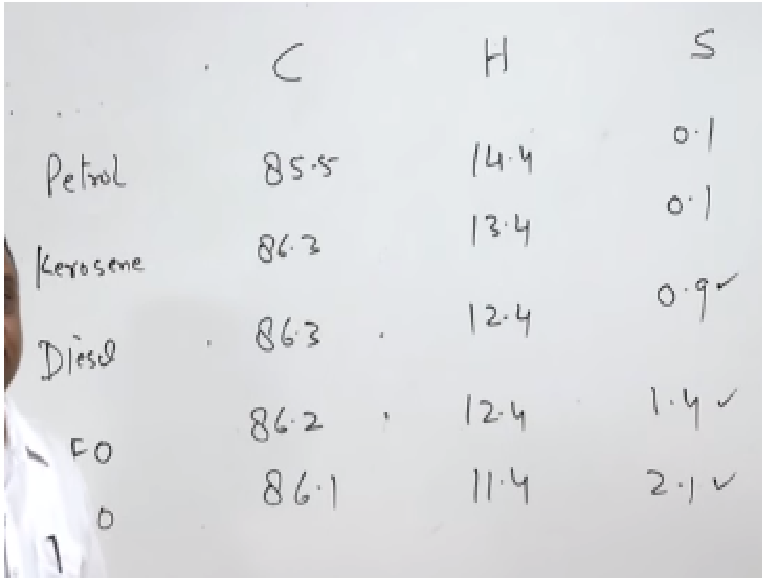

Let us start with CHS carbon, hydrogen and sulfur for petrol this is liquid fuel though petrol is not used in boilers normally diesel oil is used is in fuel oil is used in in boilers or LDO light diesel oil in the small capacity of the boilers. But the petrol the carbon is 85.5 % this is by mass hydrogen 14.4 % and sulfur is 0.1 %.

Kerosene 86.3 % carbon 30.4 % hydrogen and 0.1 % sulfur. Diesel 86.3 % carbon 12.4 % hydrogen and 0.9 % sulfur. So sulfur contain diesel is high then light fuel oil that is 86.2, 12.4 and 1.4 % the sulfur contain is increasing and heavy fuel oil 86.1, 11.4 and 2.1 the sulfur contain keep on closing.

Because sulfur is I mean it leads to the Eurozone so it damages the damage the environment also damages the boiler surface also. So sulfur contains is high in that case the special lining has to be maintained in the path of the flue gases. So the boiler body of the boiler is not damaged by this elements. Now for the oxidation of the carbon I say either carbon di oxide or carbon mono oxide form.

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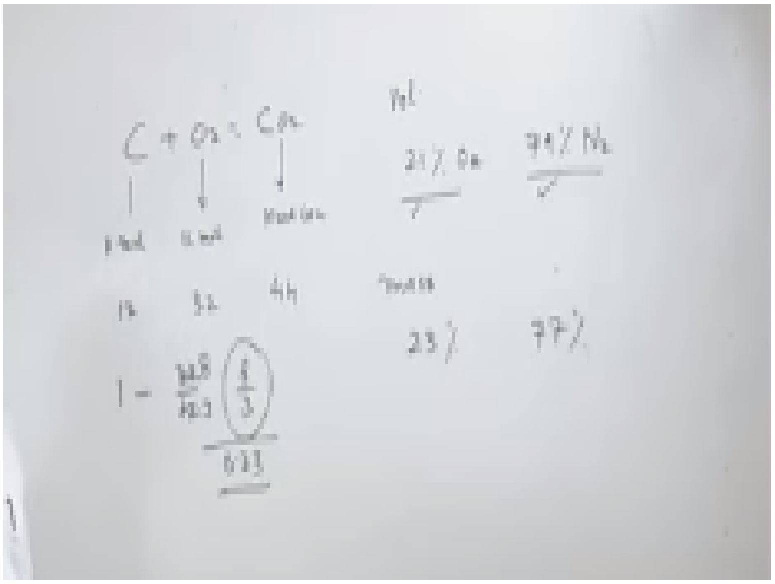

So if the carbon then C + O2 = CO2 it is one mole of C or kilo mole of C react with 1 kilo mole of O2 and will form kilo mole of CO2 or 12 KG of carbon will react 32 KG of oxygen and will form now much 32 + 244 KG of carbon di oxide. So in order to burn 1 KG of carbon how much oxygen will be required 32 by 12, 8 by 3 KG of oxygen and how much air will be required.

Now this is the amount of oxygen which is required to one KG of carbon now in order to find how much KG of air is required we should know the composition of air. Composition of air is expressed in 2 forms 1 is volumetric form 20 % oxygen and 79 % nitrogen thought they are some other gases also like carbon. But they are in traces and these are rounded off values right because if you add them it turns out to be 100%.

So air not mixture of nitrogen and oxygen only they are other like carbon di oxide in normal air is the carbon di oxide is may be 300 or 400 PPM. So four hundred PPM it means there are in traces argon gas it is also available in air. But it is also in traces so there gases are neglected because they are in bulk nitrogen is 79% by volume oxygen is 21 % of volume.

If you take by mass it turns out to be 23 % and 77 % right so once we know how much KG of oxygen is required the oxygen is only 23 % in the air. So if we divided by 0.023 we will get how much amount of air is required to burn 1 KG to convert 1 KG of carbon into carbon di oxide.

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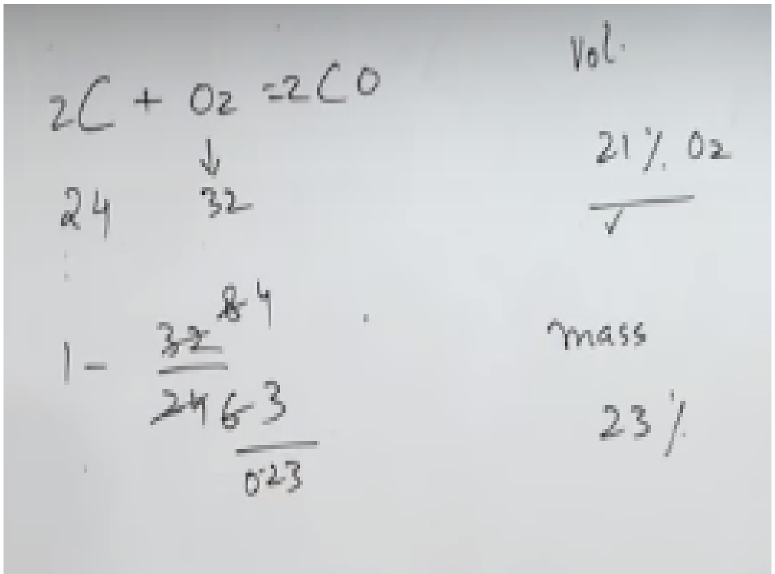

Similarly if we take the case of carbon mono oxide C + O2 = CO so how much 24 KG of 2 more means 4 KG 24 KG of carbon are required 32 KG of air right. So 1 KG will require 32 by 24 right again divided by 0.23 if both are available so suppose in the gases both carbon dioxide suppose if you take the flue gases and do the flue gases analysis and you find carbon dioxide also in carbo monoxide also.

In that case what we will do we will take the we will calculate the amount of air which is required by each of the component right and we will add that amount of air and that will be the final amount of which is required in this case.

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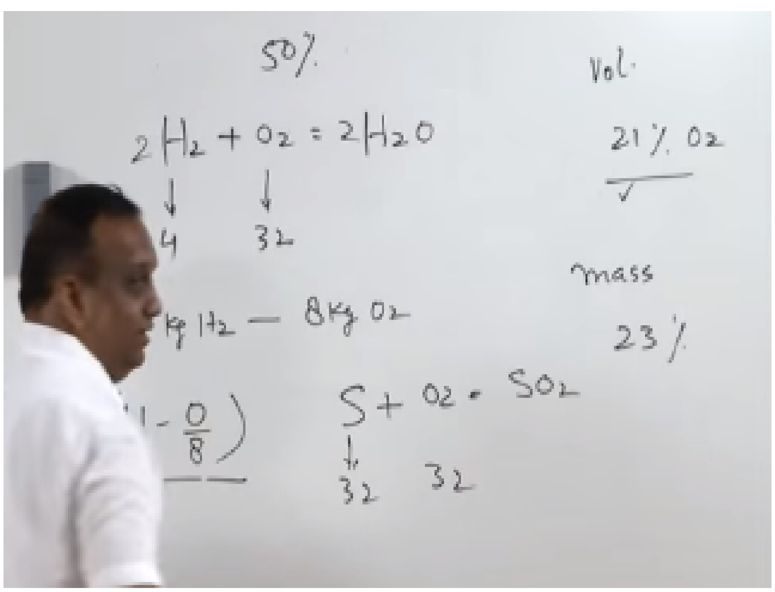

Now hydrogen is H2 + O2 = H2O so 2H2 it means 4 KG of 2 means 4 KG of hydrogen shall require 32 KG of oxygen. So 1 KG of hydrogen shall require 8 KG of oxygen but in the fuel itself you must have seen in the previous table the oxygen is also available. So that oxygen we do not require so the final amount is going to be H - O by 8 that is the free hydrogen available for free hydrogen will for burning by the air.

Because this oxygen will take some of the hydrogen right so this amount of hydrogen is subtracted from the total hydrogen available in the fuel and this balance is available for the combustion by the air. So this will be taken in the account similarly for sulfur + oxygen = SO2 right. Sulfur is 32 so 1 KG of oxygen is required for burning for 1 KG of sulfur.

So individually all this components that is how it is done when we do the analysis regarding the combustion of the boiler all this components how much oxygen is required and that is divided by 0.23 and then we will get the mass of the air some times what happens because the air is the air supplied to the boiler is not as per the stoichiometric air fuel ratio. Because the hydrogen is mixture air will be blown over the fuel and it is not a homogenous mixture.

So axis of air is supplied in the boiler and axis of air can go up to 50 % so there is always excess of air and the amount of axis of air can go up to 50 % nitrogen does not participate. There is another way also nitrogen does not participate in the combustion right so if you are able to calculate or if you able to find nitrogen with the outgoing flue gases. So immediately you can calculate how much air has been used for the combustion right.

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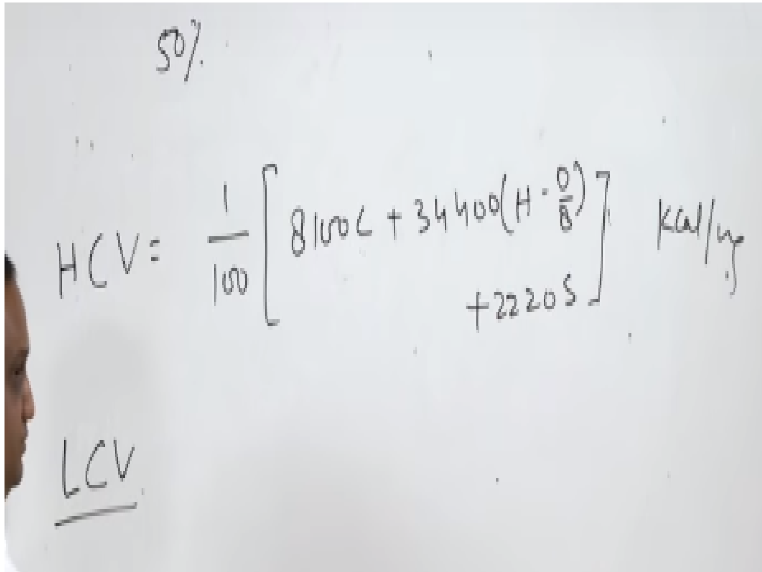

So there is a property of fuel that is higher calorific value when all this elements are oxidized enormous heat is liberated and oxidization of heat element the heat is liberated as 8100 C + 3400, H - O by 8 + 2220 S Kilo calorie per KG and this is in percentage. Suppose 86 % suppose C will be take as 86 this is how we get the higher calorific right.

In calorific value evaporation of water is not taken into heat used for the evaporation of water is not taken into the account but heat for the evaporation of water is also used so that heat is remove from the air calorific value and in that case it becomes low calorific value. It means suppose other way we low calorific value of the fuel the steam which is going with the flue gases are condensed right.

And energy coming from the through condensation of the steam is added to the flue gases that it becomes higher calorific value this is the difference between higher calorific value and lower calorific value.

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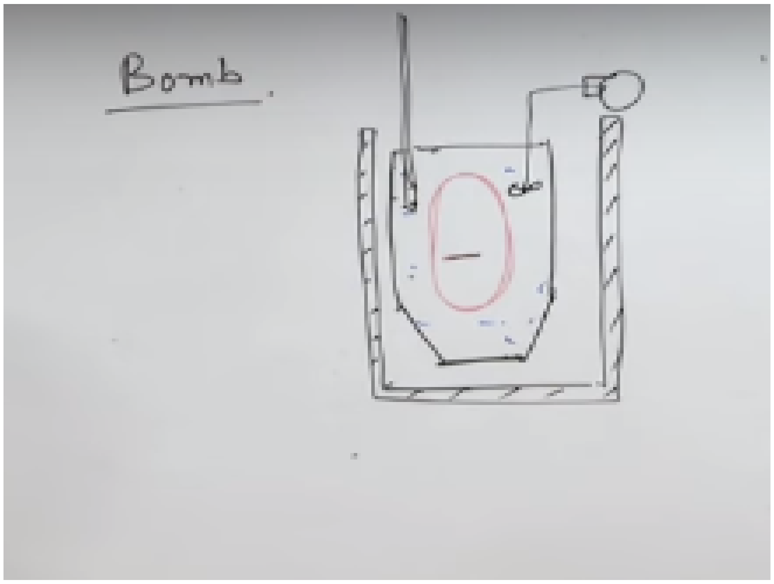

Now in order to find the calorific value of the fuel that the instrument which is known as bomb colorimeter Because finding out calorific value of fuel is also difficult task in bomb colorimeter I will just give you the schematic diagram there is a cylindrical vessel it is well insulated well insulated cylindrical vessel. Inside the vessel there is jacket sorry there is a bucket so bucket is placed inside the vessel and bucket is filled with the water, water I will show by different color.

Bucket is filled with water inside the bucket there is bomb there is a physical entity which is known as bomb. This bomb is submerge in water right it has fuel pen and certain amount of fuel is placed in the fuel pen right.

Now at the working principle is this fuel will be heated with electrical heated with the element electrical element fuel will be heated fuel will burn explosion will takes place and this heat will be taken away or will be taken by this water which is in the bucket the temperature of the water will raise that is how we will come to know calorific value of the fuel.

So here in this bucket some arrangements are made one thermometer is made we have to measure the temperature so one thermometer is fixed in this bucket. In order to have uniform temperature there is a scalar which is placed here then with the motor which stir the water and here because now we are burning the fuel along with the element. Element will also burn element fuel element which is used for heating the fuel will also burn right.

So when the heat is elaborated this taken by the water the temperature of the water raises and through heat balance we get the calorific value of water calorific value of fuel. This is for solid fuel now we want to find the calorific value of gas fuel in order because here it is difficult to find the calorific value of the gas fuel. So in order to find calorific value of the gas fuel a gas calorimeter is used.

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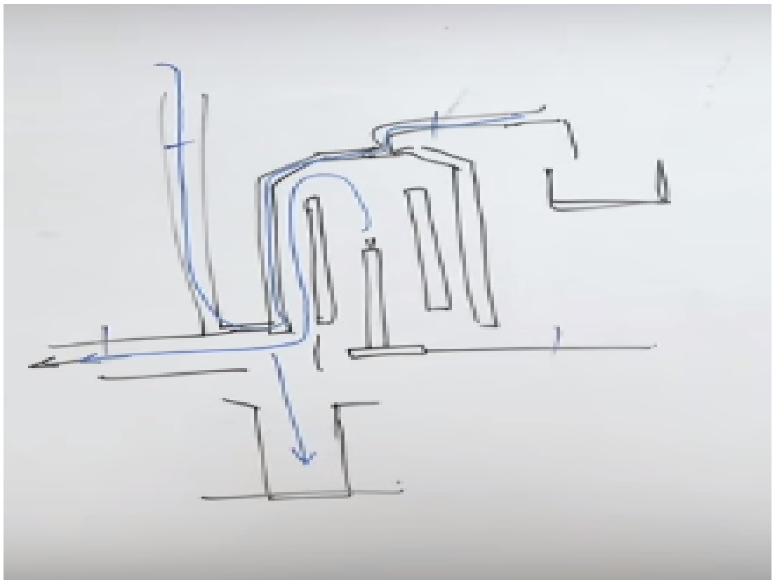

In a gas calorific meter there is a burner gas calorimeter in gas calorimeter there is a burner where gas is suppose burn gas supply is there it is house in a inverted vessel right an inverted vessel like this it is having water jacket this vessel is having water jacket and there is one water jacket here also right and water is supplied from this side and water is taken away from this side from the water jacket right and flue gases coming out of this they will go in this direction.

And water in flue gases will be condensed in a flask and here also water can be collected because water flow rate is very low. So it is collected in a bucket and then the weight of the bucket is taken. Now here in this case when the fuel is burnt flue gases go with this direction when the heat is taken away by the flue gases here the flue gases will leave from here and water will be condensed will be collected here.

From another point water will be entering from this side and it will be circulated in the jacket and it will all the heat will be removed from this side. Temperature will be measured here temperature in here inlet temperature at water inlet temperature of water outlet all this temperature will be measured for weight will be measured and through heat balance the calorific value of gases will be calculated.

This is how the two ways of calculating the calorific value of solid fuel and gases fuel okay this is all for today in the next class we will solve some numerical related with the combustion of fuel.