Fundamentals Of Combustion (Part 1)
Dr. D.P. Mishra
Department of Aerospace Engineering
Indian Institute of Technology, Kanpur

Lecture - 04
Characterization of liquid and gaseous fuel

Let us start this lecture with a thought process conscience is the celestial fire that propels us to humanity and if you look at in the last lecture we discussed about basically little bit scope about the combustion and we summarize it all the applications of the combustion and then later on move and about what is fuel, what is oxidizer and then we discussed about types of gaseous fuels and oxidizer and why we need to go for the gaseous fuel particularly in modern time and because of fact that emission is a great concern, right. So, also that efficiency is the great concern that is why we are choosing the gaseous fuel today.

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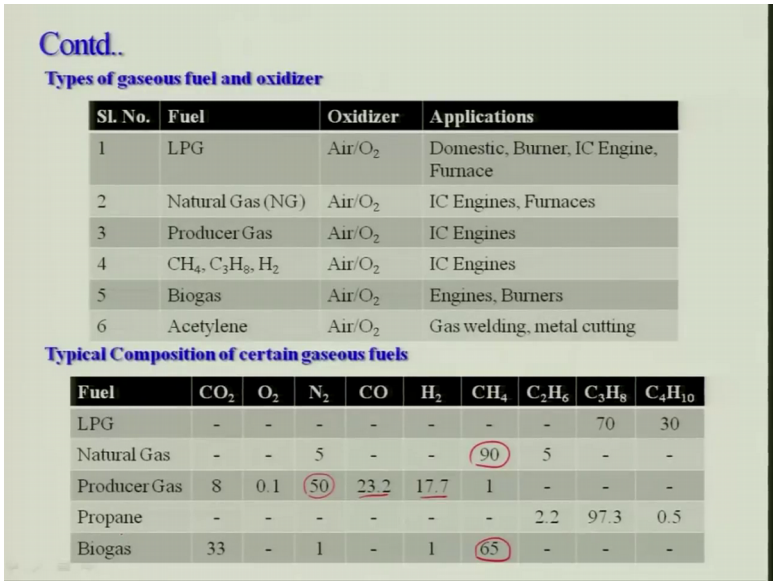

Sl. No.	Fuel	Oxidizer	Applications
1	LPG	Air/O_2	Domestic, Burner, IC Engine, Furnace
2	Natural Gas (NG)	Air/O_2	IC Engines, Furnaces
3	Producer Gas	Air/O_2	IC Engines
4	CH_4, C_3H_8, H_2	Air/O_2	IC Engines
5	Biogas	Air/O_2	Engines, Burners
6	Acetylene	Air/O_2	Gas welding, metal cutting

Fuel	CO_2	O_2	N_2	CO	H_2	CH_4	C_2H_6	C_3H_8	C_4H_{10}
LPG	-	-	-	-	-	-	-	70	30
Natural Gas	-	-	5	-	-	90	5	-	-
Producer Gas	8	0.1	50	23.2	17.7	1	-	-	-
Propane	-	-	-	-	-	-	2.2	97.3	0.5
Biogas	33	-	1	-	1	65	-	-	-

And let us look at some of the applications of this gaseous fuel and also the various types of fuel and oxidizer if you look at the LPG, LPG basically liquefied petroleum gas what is its constituents any idea butane and propane, right.

So, propane in some country only the butane will be there, but in our country, it is both right and oxidizer as I told it is air and oxygen and you can use this thing in domestic burners and internal combustion engine furnaces and other places right and natural gas

which is very much in those particularly you know in even in domestic like in IIT, Kanpur. We are having PNG, right pipe natural gas I think in your hostel it will be there I guess right and in even in your autos and other things whatever running in Kanpur.

It is having now CNG. CNG compressed natural gas, right, it can be used in furnaces and other places as well, right, but keep in mind that this is of course, my way of thinking earlier days in Kanpur we are having lot of soot you know it was fumes and soots were there, but now soot has been reduced, but this will be also producing the soot, but those soots will be nano in size. Nano soot will be dangerous than the micro soot are you getting. So, therefore, you cannot see those thing, but it will be affecting our you know system health to wait to get an extreme that it is my contextion, it may be wrong it may be right you need to find out and then you know exploit do not go by my words.

So, beside this producer gas which being produced by the basically gasification of the coal or the biomass and it will be used, I have mentioned here IC engine or the piston engines it can be used for gas turbine engine also, it can be used for burners it can be used for any other application even thermal applications like a methane I have already told you and then methane particular natural gas contains mainly methane right this propane hydrogen can be used in IC engine furnace and other applications biogas which was very popular in India, but today it is not there because we do not have you know cows in the village, right. So, cow the [FL] gas when I was very much you know popular in village may be when I was a kid.

So, it can engine can be run and burners you know you can use for domestic acetylene you might be knowing like it is used profusely for gas welding metal cutting right and acetylene like you might have observed that people are producing acetylene gas on the roadside particularly when will move in GT road, they do not buy, they produce themselves and that is a good thing according to me because they are not dependent on the market they are producing their own, right.

So, you should look at how they are producing, right. So, typical composition of certain gases am saying like for example, LPG propane is seventy percent and the butane is thirty percent do not go by that this will be like that no these are typical. It may vary from you know, what you call source to various sources like plant even in India, it will also varies right and natural gas mostly natural gas is methane, right because higher

percentage of course, this percentage may vary in some places you may find 95 percent, some places you may find 80 percent also, right rest of the thing C2S6 and some nitrogen will be there producer gas of course, it is mostly lot contains a nitrogen you know like provided it is being produced by using air, but if I use oxygen this nitrogen will go away ok.

And CO is as a fuel and hydrogen right these are the 2 major constituent of the fuel, you know CO is act as a fuel, ,right you are aware or not CO is a fuel biogas again, this is you know contains the methane 65 percent and 33 percent CO2 which is basically diluent and there is way to absorb this CO2.

So, that you will get CNG out of biogas you know you can chemical treatment you can improve quality of the biogas. So, if you look at the LPG natural gas and the propane these are perto-chemicals, whereas, the producer gas biogas can be made from the nature rather, they are sustainable whereas, the petroleum gases cannot be sustainable like after may be let us say hundred years or you know 60 years, it will not go aware why because we are consuming at faster rate and it is a limited.

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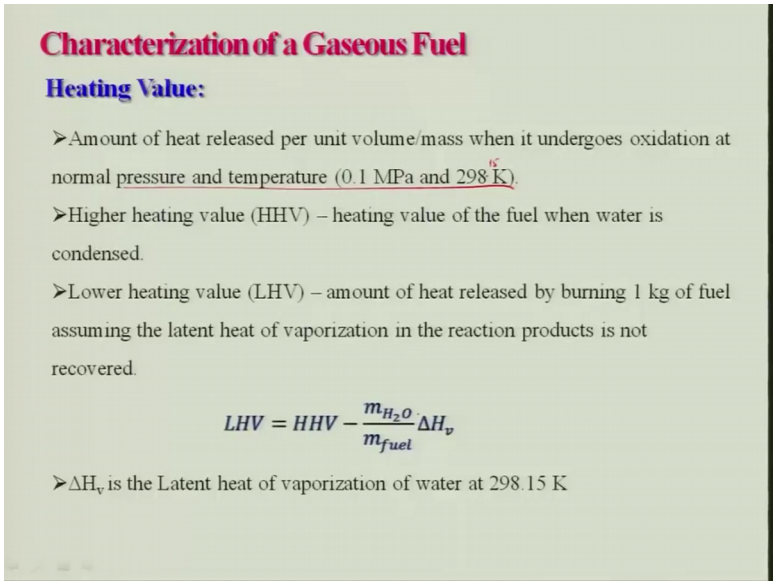

So, characteristics of gaseous fuel; so, what are the characteristics of gaseous fuel one is of course, you know heating value now if you say heating values right, what does it mean is it some amount of calories will be produced right or joules, right calorie is not being used today. Today you people are more conversion with joule right some joules

have been naturally produced per unit mass of fuel consumed or for one mole of or unit mole of fuel consumed, right, but how I will measure it question arises I should know; how to measure; is it not; how I will do that any idea you must have studied this thing. So, it has right, but I am just trying to make you to recall calorie meter right.

So, what is the basic principle of calorie meter evaporated, no-no, heated, evaporated means problem heated, then we will do for example, this do you have any idea about some very standard instrument is being used as a calorie meter bomb calorie meters any other things can I use bomb calorie meters for measuring the heating value or the calorific value of a gaseous fuel is it possible; yes or no; no, then what all if there is no is there any other instrument ha, sameval, what is that or you was a ha something else that is the some other thing you are saying fine and it is there in my book you can look at it that is basically, we will be discussing that and as I told we will be discussing about how to measure, right.

Let us look at like basically heating values, it is the heat being released per unit volume or unit mass when it undergoes oxidation at normal pressure and temperature that is very important, this part is very important because if this temperature is different and pressure is different the amount of heat released will be different or not right. So, with different then it will not be I cannot use it because I should have a some reference is basically one atmospheric pressure right and 298 Kelvin 25 degree Celsius that is the reference used as a standard across the globe.

So, and there will be also higher heating value right there will be lowest heating values higher heating value will call the heating value of the fuel when water is condensed because you condense it; that means, you will have to what to call take out some energy from the what then only it will condense; that means, it will come to the lower temperature right then only water will condense otherwise, it will not condense nah, is it not, if it is high temperature will; it water condense no right it will be lower one then only it will be condensed.

So, therefore, that heating values will be known as high heating values there will be low heating values the amount of heat released by burning one kg of fuel assuming that latent heat of vaporization reaction product is not recovered because you will have to provide this latent heat of vaporization therefore, it is a lower heating values right and lower

heating values is equal to higher heating values minus the amount of what you call mass of the water divided by mass of the fuel in to delta HV this delta HV is basically heat of vaporization of water at 298.15 Kelvin because this is the standard reference and if you look at this reference what have given is also like that on 298.15 right Kelvin.

So, if you know one of them you can find out basically if you know this high heating values right you can get low heating values and vice versa because of course, you should know the latent heat of vaporization. So, now, we will look at how to measure this heating value we have added the discussion just in the beginning of this aspect and how to measure right some of you told it is bomb calorie meter and this thing, but bomb calorie you cannot use for measuring the calorie value of gaseous value right and there is a another instrument which is known as Junkers calorie meter right.

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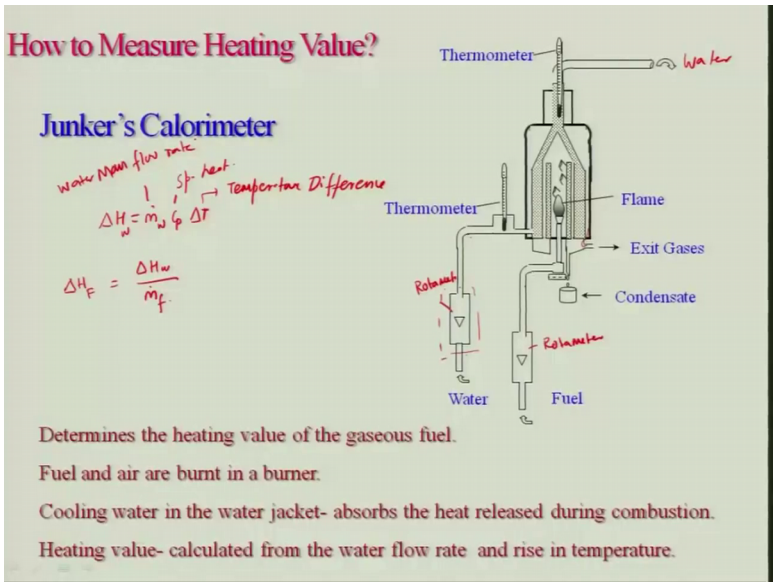

So, Junkers calorie meter looks like this. So, if you look at the water is flowing through this and what is this one any idea what you call this one. This a instrument right to measure the water floor rate right what you call any idea certainly no it is not ventury meter any anybody yes that is right rotameter, right and once what you will enter in this, you will have to measure the temperature of the thermometer, you can use any other temperature sensors, right and what will go through this remember and then it will be you know till this it will be thermometer water will be going out here this will be what is the flowing in and this will be going out water.

So, you will have to measure the temperature here and the fuel will be you will have to also measure here this rotameter and you will have to burn the this fuel and there will be a flame and these are heat exchanges, right and the hot gaseous of course, will be passing through this and going out it will go through this and then go out through this, right and then the heat will transferred from this flame to this flame water right then you will measure the inlet temperature, you will measure the outlet temperature is water and then you will also measure the water flow rate then you know the heat balance you do, then you will find out how much amount of heat being generated and you know how much fuel flow rate. It is having burnt right.

Of course, you assume that it is complete combustion is taking place, otherwise, you know if there is a suit formation and other things that has to be taking care right because that is not being burnt out you know like or this is being produced in order to take a and then you can measure of course, there might be some condensation because light will be taking place and you will use this water also I mean measure it.

And then do the calculation right this is known as Junkers calorie meter as I told you heating value is calculated from the water flow rate and rise in temperature and of course, the CP values you know like if you look at the delta H change in enthalpy will be basically water mass flow rate of waters CP and delta T. So, this from this you will get and then you know.

The mass flow rate of what you call the fuel. So, therefore, the calorie values if you look at delta H of fuel are equal to delta H w by m dot fuel right. So, CP will have to CP is your specific values and this is your temperature difference and this is mass flow water mass flow rate right. So, from these you can get very easily; is it fine?

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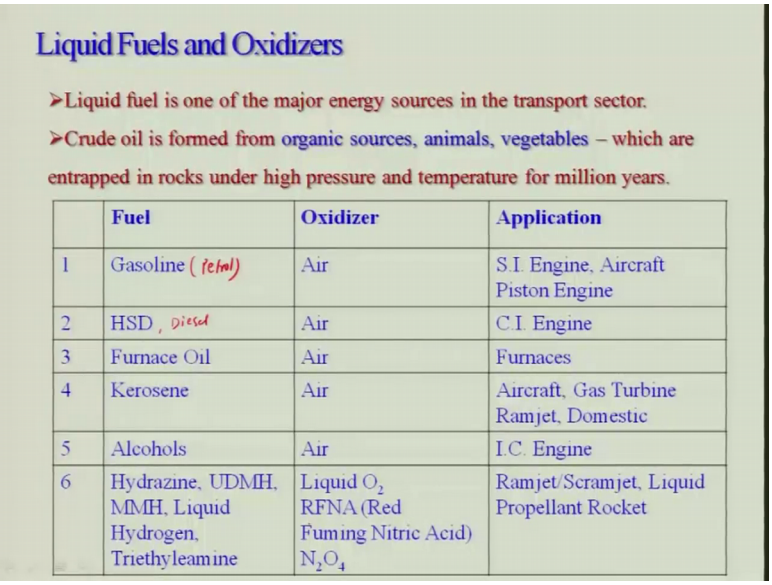

So, let us now look at the liquid fuel and oxidize the liquid fuel is one of the you know important energy force, but particularly for transport sector why because gaseous fuel to store and make it to move it is very difficult and it should be at high pressure right of course, it is being used today because of better technology right in vehicles we are using compressed natural gas, right, but you will have to carry a very big tank you know and high pressure.

So, high pressure means material thickness will be more and other thing of course, the composite material coming up. So, that will be lighter you know can the casing you can you will get that you can carry the fuel, but; however, the liquid fuel is in crude oil is formed from the organic sources animals vegetables right these are basically petroleum products which are being generated long time back and these were entrapped in rocks under high pressure temperature for million years and then you get the petroleum now we are using, right.

So, is there any idea how you will get liquid fuel you know suppose this petroleum will be over from where will get liquid fuel for our transportation any idea bio desire right, we can basically go into the bio which is sustainable, but for our country it will be difficult why to get into the bio fuel where will get bio we are not getting enough land for the food and population is higher are you getting and the consumption of the fuel is increasing at alarming rate at a very faster alarming means very faster rate. So, therefore,

it is a very big question for us what will do after these you will adopt to the present life style; that means, will have to look at the lifestyle.

So, some of the fuels I have just noted down here, but generally whenever you use a liquid gasoline or the fuel for the general application except for the space applications we go for the air; that means, whenever we are using the general in on this earth or something we are using for combustion particularly we will go for the air is cheaper right and it is a gaseous, but whenever we go for the special application like space applications or any other things then we may go for liquid oxygen and RFNA red fuming nitric acid and N2O4 right nitrogen tetroxide and there is several liquid fuels liquids are there which I will be not discussing.

But the fuels are gasoline. Gasoline means basically petrol what you use and it is being used in spark ignition engines and aircraft piston engines right and you know like in our institute we are having aircrafts and high speed diesels is a use of course, that diesel not only high speed diesel also right it is compression ignition engine and furnace all you use in furnace which is a low quality oil and, but it is being used and kerosene is being used in aircraft gas turbine engine ramjets even in domestic cooking stoves are being used alcohol in is used in IC engine, then you might be aware that in our petrol, we are adding some alcohol in order to reduce the emission and also the cost will be lower.

So, that you know another reason and beside this we use also for space application hydrogen as a fuel UDMH, unsymmetrical dimethyl hydrogen, MMH; mono methyl hydrogen liquid hydrogen and triethyle amine and several others because if you put that you know you will feel bore several fuels are there similarly for the oxidizers, right. So, what am trying to expose you people about some of the liquid fuels not all there are several like biodiesel I have not mentioned here and there are several any oil whatever is used for vegetable oil can it be used as a fuel you people might be knowing diesel when you started the engine we use what vegetable oil diesel longtime back.

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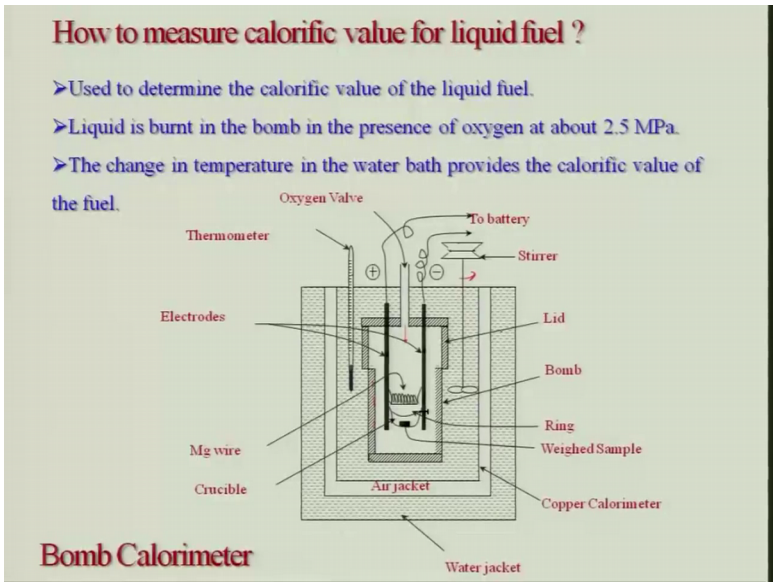

So, question arises how to measure the calorific value of liquid fuel which you have already discussed some of you told we can use the bomb calorie meter right a typical bomb calorimeter I have shown here this is your basically crucible and you can consider this as a bomb as a clo chamber bomb means what clo chamber and were this crucible is there like where you will have some examples sample weighing sample means the fuel right basically liquid.

You will weigh and put it and there will be ignition where like which will be ignited and there will be of course, ignition you should have a low electrode and it will give you sufficient amount of energy from battery or some other resources and this is your what we call chamber right this is the your chamber where the water is being filled and your having a starrer right it will be rotted.

So, that when uniformity can be maintained and this is the tempera you know thermometer whose temperature will be measured; that means, you will have to measure the initial temperature you will have to measure the final temperature when this thing and here people use oxygen right, this is the oxygen which will be coming in and then it will come in contact with liquid fuel you will have to ignite it and then there is a air jacket which is given right and there is of course, the water jacket right why this is given any idea this air jacket; that means, thermal conductivity or thermal diffusivity. So, that heat transfer; that means, heat should not transfer from this basically to you know. This

thing that is being done and then again some water is given that you know if anything even if it is going.

So, that you can also measure that, but we will do not do that. So, that no heat will be going out right and is the similar way; that means, you take the temperature reference you know the CP value of water you know the what is the mass of the water there is a mass flow rate here is the mass water and then you know how much heat is being absorbed by that how much fuel you have burnt then you can find out the calorific values right and this is known as bomb calorimeter keep in mind that this is not only used for liquid fuel it is it can be used for solid fuel as well, right.

So, this is being used profusely for measuring the calorific value and now it has been re sophisticated you can get some computer interface and eh thing very nice thing as come, but basic principle is this and according to me when you as student you should use the basic one, but if we use interface and then some sophisticated thing done what is happening you know everything will come you just put that thing this thing that value will come this is a calorie value, right, then at the result what will happen you will not learn what is happening it is like input output and that is happening today right, but it is very important to you know do this experiment.

So, that it will be can be used and keep in mind that this is important thing is that you can also you know what we call burnt this combustion presence of oxygen at a very high pressure right high pressure you can use and do that therefore, it is known as bomb calorie meter right these kind of thing. So, that reaction will be taking place and do that. Let us look at properties of the liquid fuel and. So, what are the properties of the liquid fuel any idea one is of course, calorific value any other things; no ideas.

Student: (Refer Time: 25:13).

Ha.

Student: (Refer Time: 25:15).

Low ignition temperature or ignition temperature that is rather you call it as a self ignition temperature ok.

Student: (Refer Time: 25:25).

What you call that?

Student: (Refer Time: 25:30).

Volatile; there will be some properties you know like which you will be looking am talking properties; you can; any other properties.

Student: (Refer Time: 25:45).

Ha; viscosity also, right, very good and any other thing, what I would suggest you please think about it we will discuss that in the next lecture ok.

Thank you very much.