MARINE ENGINEERING

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Lecture28

Fuel and method of firing

Good morning everybody. Today I will start the week 4th lecture on fuel firing method and some calculations. So first fuel, so boiler fuel can be solid fuel or liquid fuel, solid or liquid fuel. and solid fuel can be like previous days people are used to in use a coal wood okay many cases those are replaced by liquid fuel maybe crude oil or heavy fuel heavy high hd or high viscosity high density fluid for as a fuel so those fuel can be given into your furnace along with oxygen and it will be burning so fuel oil may contain vanadium sodium affect super heater sulfur may contain so it may contain maybe sometimes sulfur

sulfur, if it is there, then you have to reduce amount of sulfur, then you have to use. Otherwise, sulfur, what happens? Sulfur plus oxygen, it creates sulfur dioxide. Again, if it gets water, so finally, it forms H_2SO_4, H_2SO_3. So, these are actually harmful gases.

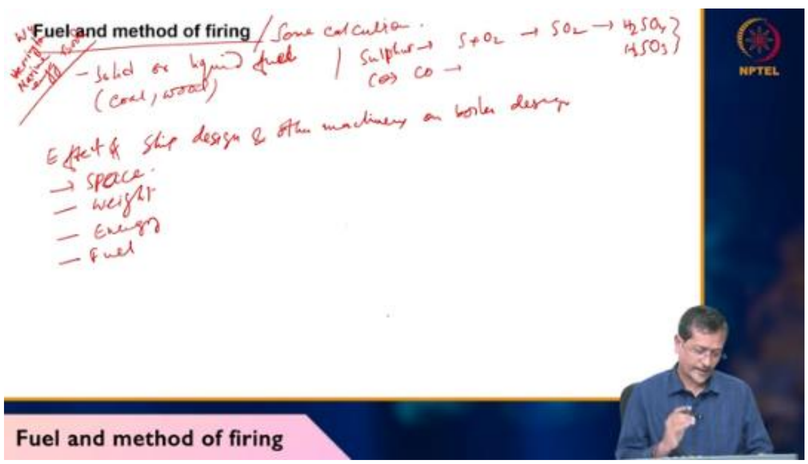
So, whenever there is any sulfur, you have to take care of all this after combustion effect. if you have some other component, let us say carbon, carbon anyway, carbon is a component of fuel. So, carbon if not combust burnt properly, then it will form carbon monoxide, so that is also harmful. in your combustion system, your main target should be to produce carbon dioxide, not carbon monoxide. Again, you have to avoid the fuel which is having more sulfur or any corrosive component.

those should be avoided. But traces, amount of sulfur and other things are there, that one you have to handle separately. Effect of ship design. Effect of ship design on other machinery. Effect of ship design and other machinery on boiler design.

And other machinery on boiler design. This portion of this lecture I have taken from marine engineering book. Marine Engineering book by Harrington. So, space is a main parameter. compact space is already better.

Because in many cases, ship machinery will not have larger space. Let us say thermal power plant you have on land. In that case, you have lots of space so you can maintain things properly. But if you have compact space, then everything must be compact. Your heat exchanger, your turbine system, everything must be compact.

space is one main criterion. Next thing is weight and how much energy you are producing and fuel consumption. handling system so fuel handling system is like when you are moving from one place to another place you need certain amount of fuel to store and let's for example if you're storing coal then you have to pulverize or you have to break the coal particle to very small particle then you can use to your system if you have liquid fuel again you have to handle that properly again these are if any fire source is there nearby that can be dangerous also so safety and storage is also very important part for shipping machineries And on generally larger the physical dimensions of a boiler for a given output, the greater its weight. So, larger dimension is obvious, weight will be increasing.



And larger dimensions maybe it will be for high power systems, for smaller compact system maybe low power systems. So, let us say you have initially taken some solid fuel, let us say coal. Now, if you want to burn the coal. So, it will take longer time like you have seen this roadside oven those people are using coal for their cooking. So, coal it will take longer time.

So, initially they will be giving some heat, they will be putting some draft air blowing extra then it will burn. But if you have coal with very small particle size, small size particle. So, in this case what will happen? The combustion will be quick. Why it is happening like this?

You see I have one bigger particle diameter d or radius diameter d and I make it to smaller particle same volume. So, small d same diameter assume. So, pi by 4. So, larger particle size is total surface area. so sphere surface area is 4 pi r square but volume will be 4 by 3 pi r cube now if i break it into two so diameter will be changing okay so volume will be same because total mass is same so pi by pi 4 by 3 pi d r cube

2 times equals 4 by 3 pi capital RQ I can say. So, I am getting R equals 2, smaller I will calculate. So, I will be getting R by 2 1 third. So, R capital R into 2 power 1 third.

So, this formula I am getting. So, if I calculate volume surface per bigger one S equals 4 pi R square smaller one 4 pi small r square. So, 4 pi capital R into 2 power one third. Now, if you can compare small s and capital S. So, you can see this capital small s is having total surface area is larger than smaller s 1 or I can write 4 pi

r square so square so 4 pi r square 2 power 2 by 3 okay therefore s equals 4 pi 4 pi square means s into 2 2 power 3 okay so you can see this surface area increased for smaller diameter particle now why surface area increasing better So, whenever oxygen molecule reacts with any fuel, so it will be acting on the surface actually first. So, surface part will interact with oxygen and combustion will be occurring. And when combustion occurring, it will be exothermic reaction. When exothermic reaction happens, so surface part will be burnt.

then hot gases will be removed, then oxygen will be penetrating into the center part and it will be burning completely. Now, if you have a smaller particle, the oxygen particle can reach quickly to the center part and it will be heated quickly. It will be reaching to your burning temperature or combustion temperature quickly. So, combustion will be quicker. It is getting oxygen quickly and again it is getting heated up quickly.

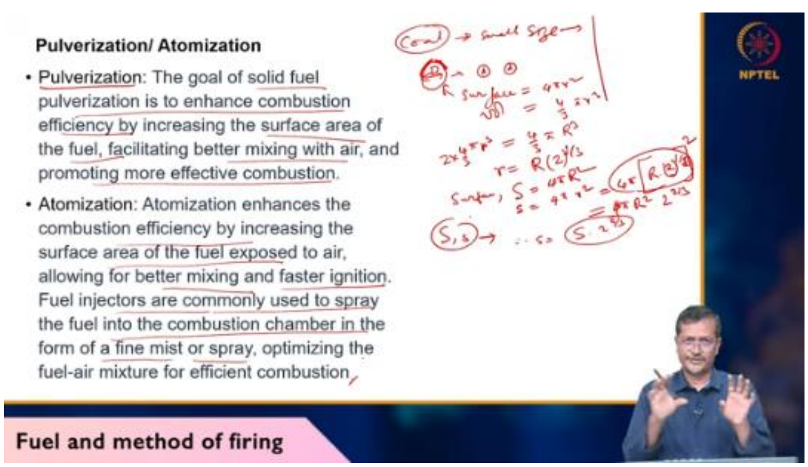
So, the smaller particle is better. It will have a larger surface area. So, smaller particle means So, you can see this pulverization definition. The goal of solid fuel pulverization is to enhance combustion efficiency.

Combustion efficiency means quickly the particle will be burning and it will be reacting with oxygen and there will be possibility of now producing carbon monoxide or ash because it is getting proper oxygen, properly heated up and complete combustion possible. Surface area increasing and facilitating better mixing with air and promoting more effective combustion. This is the purpose of pulverization. So, any coal-fired unit or solid-fired unit will have a pulverization unit where they will be breaking the solid particle, solid fuel into very, very small tiny particless so that then it will be injected into the combustion chamber. atomization and the term will be there for liquid fuel system atomization enhances the combustion efficiency by increasing surface area of the fuel the same strategy you can apply big water fuel particle is a diesel particle you take and you break into smaller particles smaller particles have more surface area so oxygen will be interacting on the surface and temperature will be it will get proper temperature it will be reaching to burning temperature quickly combustion will be quicker

So, better mixing will be possible, faster ignition also possible. Fuel injectors are commonly used to spray the fuel. So, one nozzle type thing will be there. So, the nozzle will be spraying the fuel. When it is spraying, actually it will be creating very tiny particles, small particles.

That is called atomization. The fuel into combustion chamber, a form of a fine mist or spray, optimizing the fuel air mixture for efficient combustion. okay for efficient combustion you are making very small particle increasing surface area surface increasing means oxygen interaction will be there temperature will be rising quickly burning will be proper there is possibility of less possibility of producing carbon monoxide or or ash or residual carbon because it may have sufficient oxygen to burn completely okay So, any boiler furnace system, they will have the pulverization system, if solid fuel is there or liquid fuel is there, then in that case atomization system must be there. The atomization system is simple, the nozzle will be working, but in the pulverization system, you must have one ball mill to roll the element will be there.

So, there will be rolling element, when solid fuel is passing through the rolling element, heavy rolling element, so it will be breaking into very tiny particle. Calorific value. So, whenever you are talking about fuel, so fuel will have calorific value. Calorific value means calorie term is there. You can remember, you may have studied in your school books.



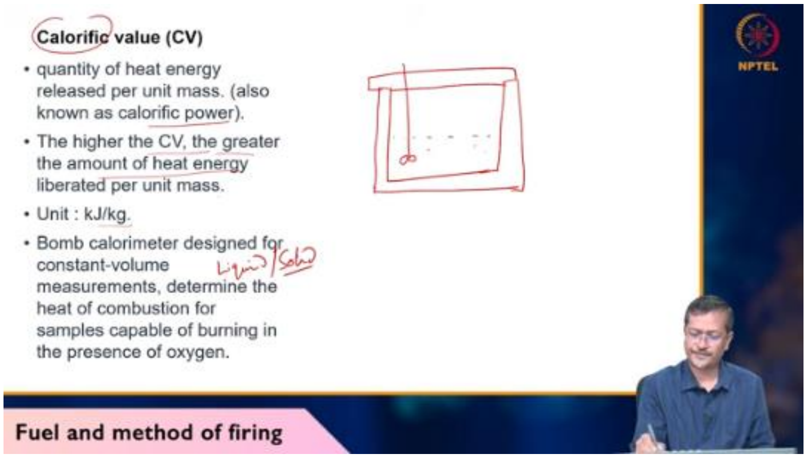
Calorie means measuring unit of heat, not temperature. temperature measurement will be sensed in thermometer, but calorie you cannot sense. the quantity of heat energy released per unit mass also known as calorific power. The higher the CV or calorific value, the greater the amount of heat energy liberated per unit mass. Unit will be kilojoule per kg and it can be different also.

For example, calorie per gram also I can say. a warm calorimeter designed for constant volume measurement determine the heat of combustion of samples capable of burning the presence of oxygen so normally this will be used for liquid or solid liquid or solid fuel okay Now, how to measure this calorific value? Because thermometer can measure your temperature. To measure calorific value, this warm calorimeter will be there.

This warm calorimeter will be like this. They will have one solid vessel, adiabatic vessel actually, very strong vessel it must be. It should not break. And it should have one lid. The lid will be like this.

Now, that is also solid vessel. So, it must be closed properly like pressure cooker you have. So, lid will be closing strongly so that no air or fluid can go out. But in pressure cooker normally in India used the heat loss will be there on surrounding because this will be metallic. But if you insulate it properly then that can be used as a calorimeter also or bomb calorimeter also.

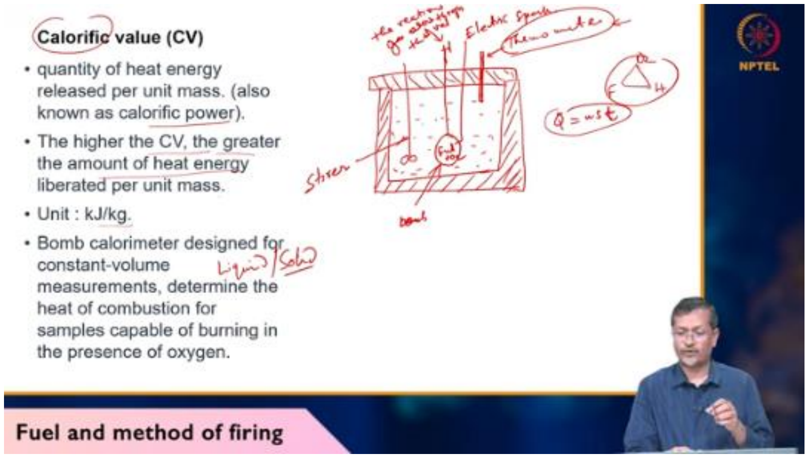
So, now you will have one stirrer. You have maybe water is there. you take your sample here this called a bomb okay this is stearer and there will be one thermometer thermometer you take your sample here this called bomb okay this is stearer and there will be one thermometer thermometer meter and there will be one electrical spark system this will be electric okay now through this channel there will be one ball okay so you take fuel plus oxygen and it will be controlled through this valve okay the reactions



that involves gas or oxygen, gas enters through this valve, gas or air enters or oxygen through this valve. So, inside this fuel plus oxygen is there, there reaction will be happening. So, when reaction is happening, it will be exothermic reaction only small amount of fuel is a diesel you take uh sorry wood a small portion of wood you take pulverized wood mixed with oxygen now initially you don't have temperature i already told that to burn something you need three things uh fire triangle i told already oxygen fuel and heat okay so oxygen fuel already you have and you have to give heat or fire source so fire source you are creating one spark and you give a fire source then fuel will be burning so it will be burning because of exothermic reaction heat will be produced heat will be increasing the water temperature because this is whole thing is submerged in water when water temperature increased you measure the water temperature how much increase using thermometer let's say 10 degree increased okay and you have let's say 500 milliliter water inside your system now 10 degree increase 500 millimeter water was there so

Then how much heat is there? So, you can calculate Q equals MST mass into specific heat of water and T means temperature increase. Using this formula, how much heat generated you can calculate directly. So, this is called bomb calorimeter and the vessel must be adiabatic. No heat should be interacting from outside or inside.

From outside heat should not enter or from inside heat should not go out also. So, this is the basic principle of your bomb calorimeter and it is used to measure calorific value or amount of heat stored in a fuel. Normally solid or liquid fuel will be used to burn here inside the chamber. whenever you are talking about fuel, solid, liquid or gaseous, gaseous fluid may be your natural gas, solid fuel may be your coal, wood, liquid fuel may be your petrol, diesel. So, they will have lower calorific value, upper calorific value.

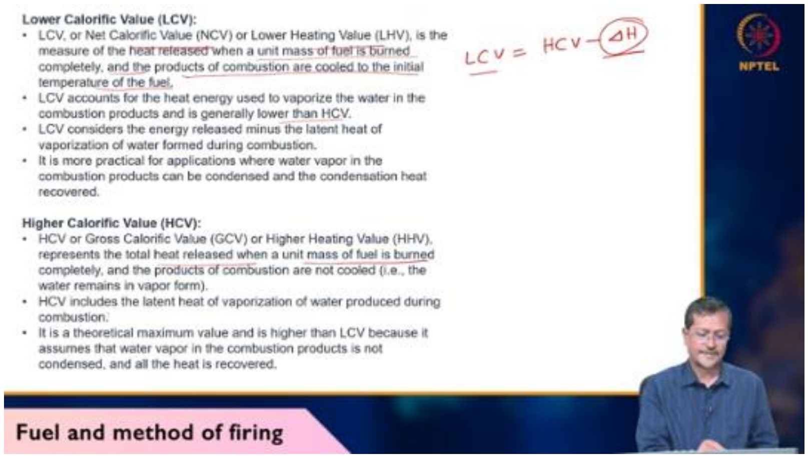


In previous cases, you measured calorific value only. I did not spoke about lower or upper. Now, try to understand what is lower, what is upper. Lower calorific value or net calorific value or lower heating value is the mass of heat released when unit mass of fuel is burnt completely. and the product of combustion are cooled to the initial temperature of the fuel.

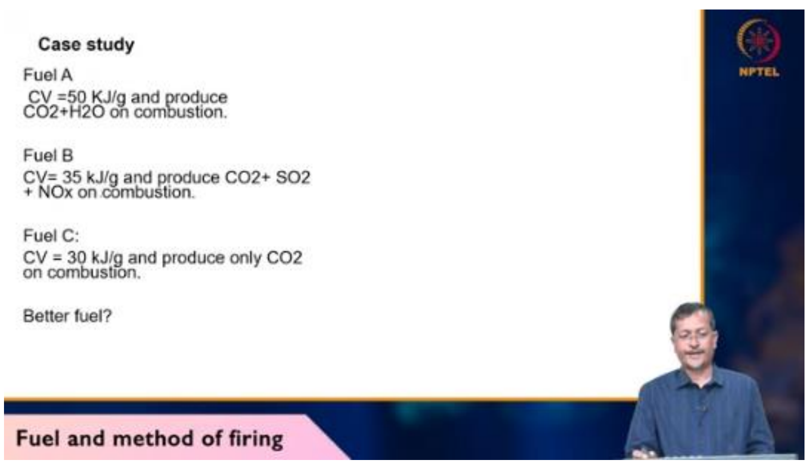
LCV accounts for the heat energy used to vaporize the water in combustion products and is generally lower calorific value. LCV equals HCV minus some heat actually okay so lcb is the lower one because hcv will when you are heating your burning fuel so your water molecule if there is any water content in your fuel so that will take some heat and it will be taking latent heat actually sensible as well latent heat and that heat actually you cannot use for your proper purpose because whenever is gaseous form, it will be having this latent heat within it and it will go out. So, that is not useful for you.

So, that portion you have to minus, then you are getting your LCV. So, HCV or gross calorific value or higher heating value represents the total heat released when unit mass of fuel is burnt completely. So, total heat you are getting, but you are not calculating how much water is there. Whenever calculating lower calorific value, that will be used for your engine calculation, engine how much power it will be getting. Higher calorific value may be very high, but some water content is there, so that is not giving you any value.

So, finally, you have to take the lower calorific value, the digits, then you have to calculate further for system efficiency. ACV includes the latent heat of vaporization of water produced during combustion. So, if any water particle is there, that also you have to consider here. It is there theoretically maximum, theoretical maximum value and is higher than LCV because it assumes that water vapor in the combustion products is not condensed and all the heat is recovered. But in LCV, more practical and application water vapour combustion product can be condensed and the condensation heat recovered.



case study just one example it is taken okay so let us say one case study i have one three fuels one is calorific one is having calorific value 50 kilojoule per gram and it is producing carbon dioxide and water for example i have let us say ch4 If you burn it, then with oxygen plus oxygen, so it will create CO2 plus H2O. I am not doing the balancing. How much, how many water oxygen will be, oxygen or methane will be required? I am not balancing it now.



So, in another case, I am getting carbon dioxide water plus NOx also, plus sulfur dioxide also. produce carbon dioxide, sulfur dioxide, H2O, I can write, plus H2O plus CO2. So, this one like this, this one this. And another, I am getting CO2, produce only CO2 on carbon, CO2 plus H2O. In one case, I am

trying to get just some mistake is here this is co okay in first case i am getting co plus co also there second case i am getting h no nox so2 h2o co2 in third case i am getting co2 plus h2o okay so which fuel can be better now you can see the calorific value is higher for a but lowest in C but C is giving me carbon dioxide and water So, if you ask me to choose which is better, I will take fuel C because it is not giving me any harmful gases. Fuel A is producing carbon monoxide, which is harmful. I told carbon dioxide is not harmful actually.

Combustion engineer, all combustion engineers or researchers, they will try to produce carbon dioxide, not carbon monoxide. Carbon dioxide is already there in atmosphere. Even we are exhaling also, sometimes we are inhaling a certain amount of carbon dioxide. Trees are surviving because of carbon dioxide. So that is not harmful although greenhouse and other theories are there so that we are not considering here.

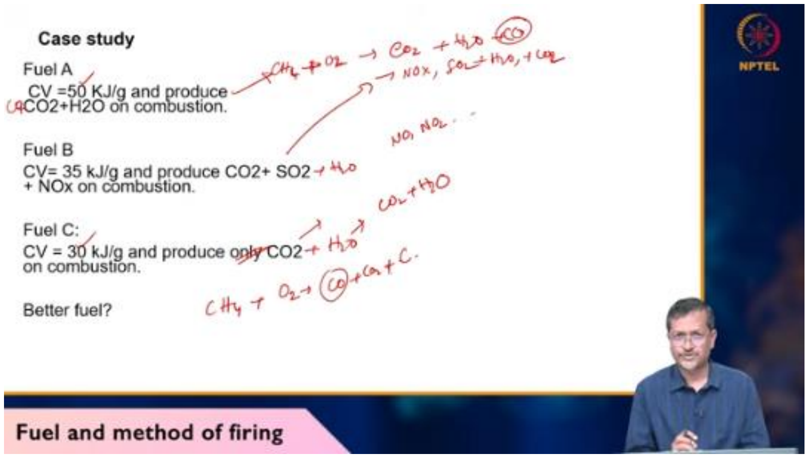
Carbon monoxide is harmful. So combustion engineer will target not to produce carbon monoxide. And fuel B, it is producing SO2. SO2, again, it is dangerous. SOT plus H2O, it will be producing acid.

NOx, nitrogen 5 oxides will be there. NO, NO2, N2O3. So, 5 oxides will be there because nitrogen has 5 valences. So, those will be creating harmful gases like nitrous acid, nitric acid. That is also not good for your environment.

So, fuel B also harmful. So, I will not take fuel A or fuel B. I will take fuel C because it is giving only carbon dioxide and water. So, in boiler case also your target will be to produce carbon dioxide and to minimize SO2 or NOx production. Now, in certain field you have higher amount of oxygen. So, what will happen?

Let us say simple I am giving you an example CH4 is there and oxygen very high amount is there. What will happen? It will be producing carbon dioxide and water. okay but it will not produce carbon monoxide because carbon all the carbons will get enough oxygen and it will be producing carbon dioxide so people will be happy and when carbon dioxide is produced the flame will be almost invisible or bluish color some flame will be there but if you have less amount of oxygen and you are producing CO plus CO2 plus other component so CO is harmful so and maybe some carbon particle also be produced so if you see Chula or rural people there will be burning fuel wood or something so lots of black smoke will be coming black smoke ash it will be containing lots of carbon particle so when carbon particle is there it is possible that it will be producing carbon monoxide also so that is actually harmful

But if you see an oven, Indian oven or Indian oil, they are supplying gas to your household or kitchen. So, normally you will not see any black ash coming or black soot coming from your oven. So, that system is designed properly. So, whatever fuel is there, it is getting proper oxygen. So, it is not producing any C or CO, it is producing carbon dioxide.



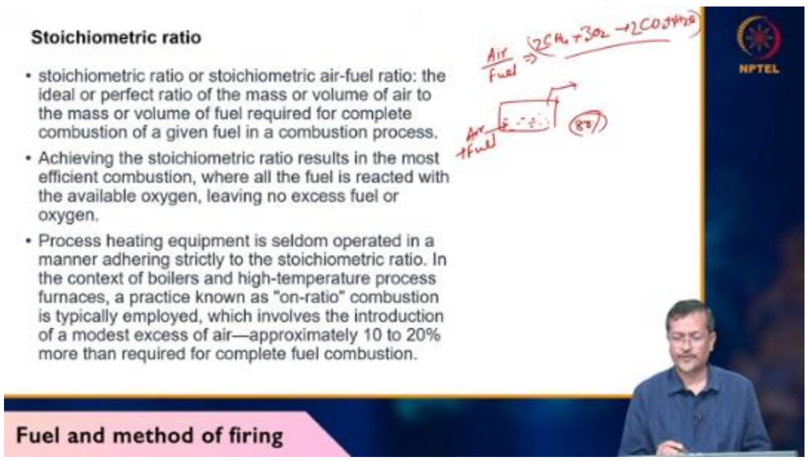
okay so so that's why the utensils will not be blackened but if you see wood someone is burning and some utensil is there so that will be black because some carbon particle you get deposited on your pots okay uh so that is harmful if you have carbon monoxide carbon dioxide also can deposit in your lungs that is also harmful that's why smoking smoking the smoke when you are talking about that means it is having carbon particle so it is getting deposited in your lungs that is also harmful stoichiometric issue Stoichiometric ratio or stoichiometric air-fuel ratio, the ideal or perfect ratio of a mass volume of air. So, air and fuel. So, this ratio you have to maintain. This is certain amount of CH_4 plus oxygen.

You need certain CO_2 plus H_2O. I think you need 2 oxygen, 4, 2. So, 2 two and oxygen you need four six so three two c h four eight four okay now you can see this equation three or two plus plus $4H_2O$.

This proper amount of oxygen you are giving, then your combustion is proper. You are not giving excess oxygen or lower oxygen. Lower oxygen, I already told that it can produce carbon or carbon monoxide. That is harmful. But what if I give more oxygen, so I will not produce any carbon monoxide.

It will be good for environment. There is another question. Question is that when you are burning inside boiler, you are giving air Now, you are giving extra air, extra air means around 80 percent, 80 percent nitrogen you are giving about. Extra air you are giving means you are giving more nitrogen which is not useful and you are giving extra oxygen also.

So, what will happen extra nitrogen, oxygen whatever is there, so that will take certain amount of heat and it will be heated up and it will go out with your flue gas. there will be heat loss if you are giving very high amount of air and you are thinking less i will not produce any carbon monoxide i don't want to harm your my environment so in that case you put lots of oxygen finally your heat loss will be higher so when heat loss is higher your whole efficiency will be lower your you have to put more money for your fuel because your burning fuel but it is getting wasted because flue gas is taking lots of heat from your combustion chamber So you have to give actually ideal air fuel ratio or stoichiometric ratio, that ratio you have to maintain. Now the scientist says like 10-20% extra fuel you keep, not too much, 10-20% extra fuel if you are keeping then combustion will be complete and small amount of heat is going through this air, that is fine. But you are not having environment and you are getting optimal efficiency.



But if you are giving exact amount of air-fuel ratio, then there is possibility that some carbon particle will not get burned completely. So, they may produce carbon or carbon monoxide that can be harmful. So, their suggestion, increase little bit, not too high. So, 10-20% increase and you use it, that is fine. So, you can read this now.

Assuming the stoichiometric ratio results in the most efficient combustion, when all the fuels is reactant, with available oxygen leaving no excess fuel or oxygen okay but scientists says keep small amount of higher oxygen process sitting equipment seldom operated in manner adhering strictly to the strike committee ratio in the context boiler and high temperature process furnace a practical known as on ratio combustion is typically employed which involve induction of modest excess air modest not too high approximately 10 to 20 percent more than required to complete the combustion so fuel properties so fuel first thing is viscosity okay so if you have very high viscosity fluid pressure drop will be higher so whenever you are putting different viscosity fluid you have to consider whole combustion thing how things will work in some cases you have to consider your flammability flammability you need to know because of two reasons. One is that when you are storing, it should not burn quickly.

So, if there is a small fire source, it should not burn and there should not be bursting or any dangerous effect. And again, if you have lower flammability, it may be burning quickly in your combustion chamber. So, you have to know your flammability. Some more thing you have to know like flash point. Okay, some fuel will be flashing quickly, so that point also you have to know.

Some cases you have to know pour point. Okay, these are given in your book D.A. Taylor, D.A. Taylor Marine Engineering book. Okay, this theoretical thing, just you go through it.

Okay, viscosity, flash point, pour point, these definitions, please go through it.