Fuels, Refractory and Furnaces

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Lecture No. # 09

Principles of Combustion: Concepts and Illustrations

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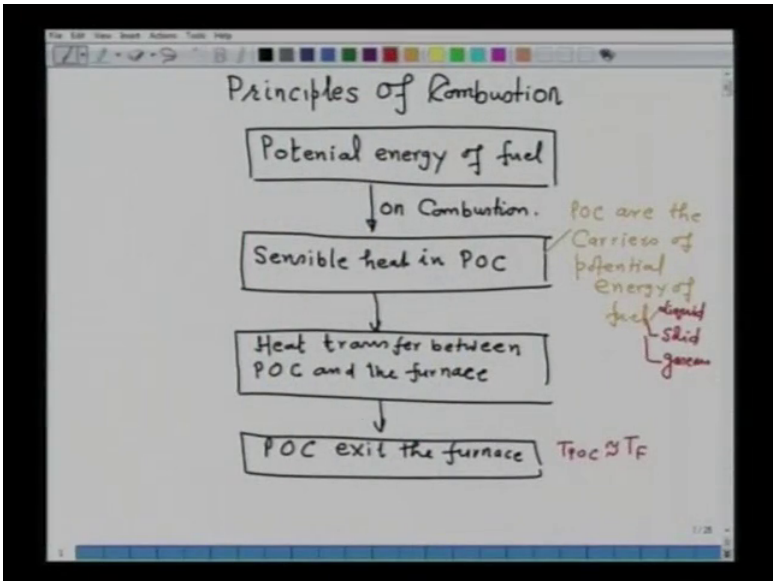

Today, we will talk on principles of combustion of fuel. Now, all of you are aware that, energy from fossil fuel is obtained when fossil fuels are combusted in an oxidizing medium, which it could be air or oxygen; mostly air is used for combustion of fuel. It could be fossil fuel, or it could be synthetically prepared fuel, for all types of fuels, the potential energy of the fuel is obtained through combustion. So, what happens, on combustion, the potential energy of the fuel is released in the products of combustion.

And, these products of combustion, transfer their heat to the object which is being heated, or, for example, in the furnace, or to the charge, for example, if you are heating bloom, billet or slab in a reheating furnace, or heating calcium carbide, calcium carbonate in a rotary kiln for cement production, whatever be the furnace maybe, the potential energy of the fuel is

obtained in the product of combustion, and through heat transfer from product of combustion to the charge, or to the furnace, the furnace or charge gets heated up.

After heating, the products of combustion exit the system. So, if I want to show the mechanism of release of potential energy of fossil fuel, or for that matter, any type of fuel, then, it can be shown as follows. For example, the potential energy of fuel, potential energy of fuel, that is, on combustion, on combustion, it is transferred in the form of sensible heat of product of combustion, sensible heat in POC; now, POC stands for products of combustion. Now, essentially, POC, in fact, they are the carriers, they are the carriers of potential energy of fuel. Mind you, the fuel could be liquid; it could be so,lid, or it could be gaseous. It could be fossil, or could it be a synthetically prepared one. In all cases, the potential energy of the fuel is transferred into the sensible heat in products of combustion.

Now, these product of combustion, they in fact, the heat transfer, heat transfer between products of combustion and the furnace, or charge, whatever object to be heated up, then, this heat transfer occurs, furnace gets heated up, or the charge gets heated up, and at the end of this, the products of combustion, the products of combustion exit the furnace. Now, here the products of combustion, they exit at a temperature, which is at least equal to the furnace temperature. So, therefore, the temperature of POC is at least equal to temperature of the furnace. This has to be there, otherwise, the furnace will be overheated, or under-heated, in both the cases.

So, in conversion of potential energy of fuel to the useable heat in the furnace, it is the products of combustion that are important, which transfer heat to the charge. And, another important thing, in case of fossil fuel derived energy is that, the products of combustion exit the system, here, for example, in furnace, at least at a temperature which is equal to the furnace temperature. So, imagine, if a furnace temperature is 1000 degree Celsius, or 1200 degree Celsius, then accordingly, the product of combustion will also, exit at that particular temperature.

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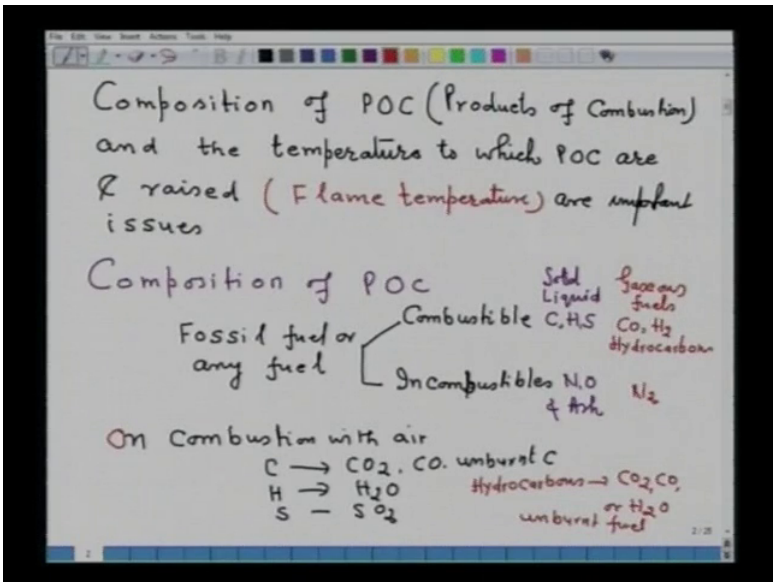

So, what is important in case of combustion is, that means, composition of POC, composition of POC, let me write down here, at least, POC stands for products of combustion, throughout my lecture on combustion. Products of combustion. So, composition of POC and the temperature, and the temperature to which POC are raised, POC are raised, which is called flame temperature, is called flame temperature are important issues, are important issues, when we deal with the combustion of fossil fuel. That means, what we have to consider, the composition of POC and flame temperature. So, as such, first, I will consider composition of POC. Composition of POC, now, as from the earlier lecture you are aware, all fossil fuel contain combustible component, as well as incombustible component.

So, fossil fuel, or any fuel, or any fuel for that matter, it contains one combustible component and another, they are the incombustible component; incombustibles. Now, the combustible component in case of, say solid fuel and liquid fuel, the combustible components are carbon, hydrogen and sulfur, in most of the cases; where, incombustible components are nitrogen, oxygen and ash. So, these combustible and non-combustible components, they are for solid or liquid fuels. For and gaseous fuels, in gaseous fuels, the combustible components are carbon monoxide, hydrogen and hydrocarbon, and hydrocarbons; whereas, incombustibles are nitrogen. They are mostly the incombustible components, in case of gaseous fuel. Now, what happens, say, on combustion, say, if you take air, for a combustion with air, the carbon is converted to C O 2 or C O. Both possibilities are there, or unburnt carbon can be present. H is

converted to H 2 O. Sulfur is converted to S O 2; whereas, the hydrocarbons, they are converted to C O 2, C O or H 2 O or un-burnt fuel.

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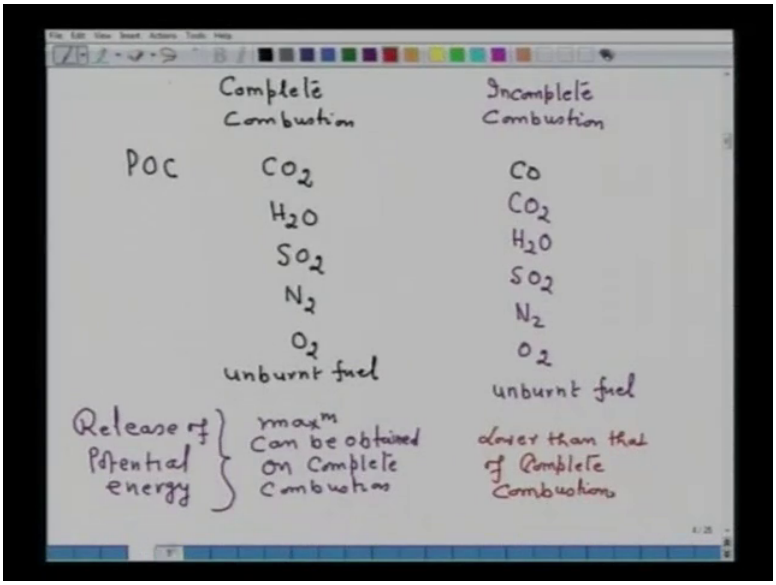

Now, if you want to say the components which are present in POC, for example, if you take here, products of combustion and here, we say, if there is complete combustion, if we have complete combustion and another case, if we have incomplete combustion; incomplete combustion. So, for complete combustion, the products of combustion would be C O 2, H 2 O, S O 2 and if you use air, then possibly, nitrogen will also be present, and oxygen may be present, depending upon the amount of air that is being taken. The incomplete combustion will have C O, C O 2, H 2 O, S O 2, N 2 and O 2. The only difference between complete and incomplete combustion, with regard to the products of combustion, is mostly in terms of C O or C O 2. If there is a complete combustion, then, the POC will have C O 2; if there is incomplete combustion, then, the POC will have C O; and in case of incomplete combustion, it is also possible, some unburnt fuel may be there; some presence of unburnt fuel may be there. However, in case of complete combustion it is also possible, the presence of unburnt fuel.

So, now, if you want to say, the release of potential energy, the release of potential energy, if there is complete combustion, then, it will be maximum; that means, the maximum potential energy of the fuel can be obtained, can be obtained on complete combustion, on complete

combustion; whereas, in case of incomplete combustion, the energy content of POC will be lower than that of complete combustion, than that of complete combustion.

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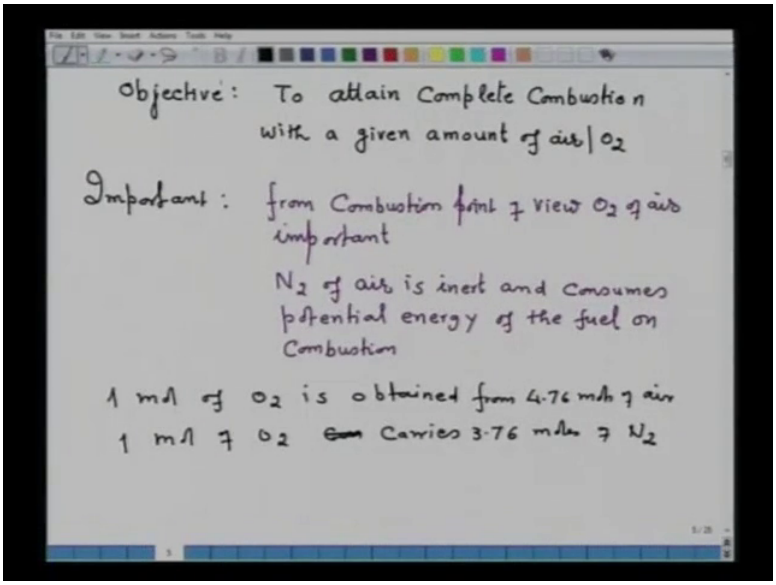

So, what is the objective of our combustion? Objective of combustion is to attain complete combustion, attain complete combustion, with a given amount of air, a given amount of air or oxygen, if oxygen is used as a combustion medium. So, now, it is important to note, it is important to note that, from combustion point of view, from combustion point of view, oxygen of air is important; oxygen of air is important; whereas, nitrogen of air, nitrogen of air is inert and consumes potential energy of the fuels, and consumes potential energy of the fuel on combustion; because, as you noted earlier, that the potential energy of the fuel is available in the form of products of combustion, or products of combustion are the carriers of energy. So, nitrogen will also consume the potential energy of the fuel, without giving any heat to the combustion process. That means, it will also be heated up from some temperature to the flame temperature.

Now, we also know that, one mole of oxygen, one mole of O 2 is obtained, is obtained from…

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