Fundamentals of Combustion (Part 2)
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Lecture – 79
Lecture 39: Emission Control Methods

Let us start this lecture with a thought process from Johan Rockstrom.

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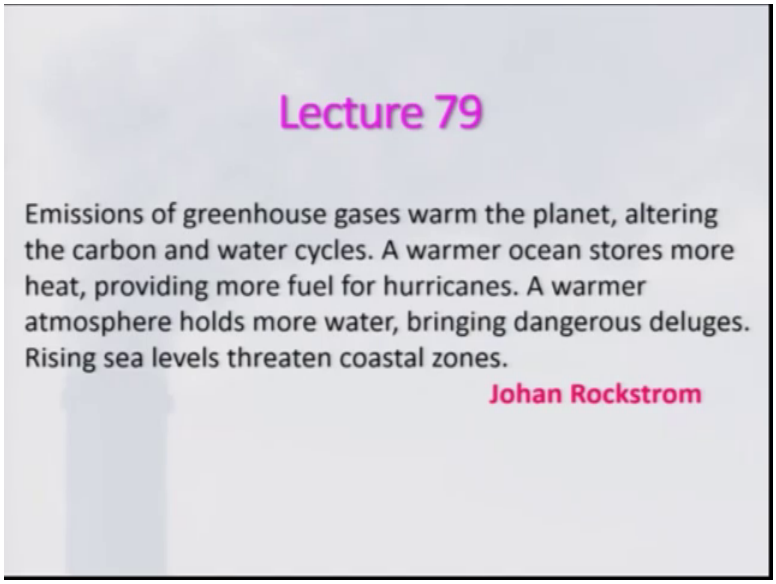

He says emissions of greenhouse gases warm the planet, altering the carbon and water cycles. A warmer ocean stores more heat, providing more fuel for hurricanes. A warmer atmosphere holds more water, bringing dangerous deluges. Rising sea level threaten the coastal zones. And some of this thing we are experiencing nowadays and let us recall that what we learnt in the last lecture. In the last lecture we discussed about how to take care of expressing the emission level at different oxygen level as per the standard even though you are measuring at different oxygen level.

And, beside this you can also express the emission level in terms of emission index which is independent of oxygen level. Today we will be looking at how to control the emission from the combustion system.

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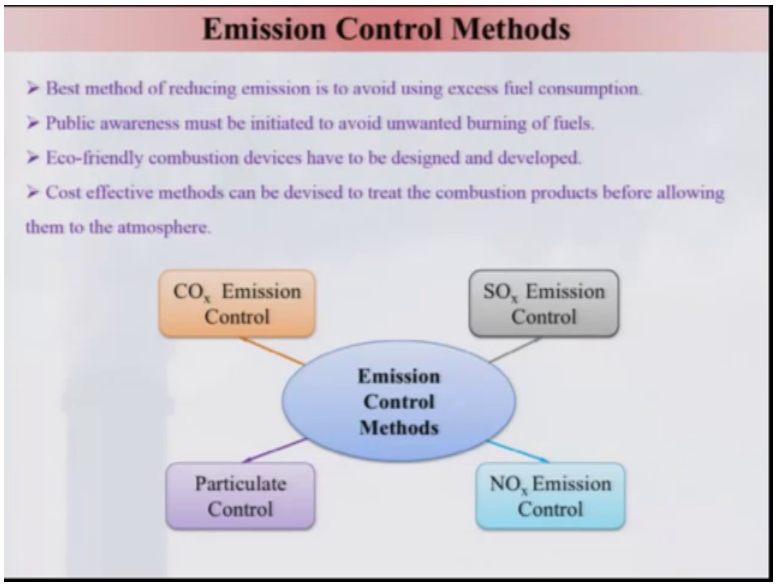

The best way of reducing emission is to avoid using excess fuel consumption and that we do there is no other way out. Of course, when you want to do that you will have to create a public awareness such that they will not use the burning of fuels in unnecessary manner. The way people so for their own enjoyment and self aggrandisement.

And eco friendly combustion systems should be designed and developed such that it will emit less amount of emission from those systems. And that is the things where the fundamental of combustion plays a very important role and besides this the cost effective methods have to be devised to treat the combustion product, before allowing them to atmosphere that is by this way we can really help in polluting the atmosphere to a larger extent.

And, if you look at when you talk about the emission control methods we are basically talking about CO x emission control and particulate control and also the NO x emission control and, the SO x emission control. So these are the four limbs of emission control so far the combustion system is concerned.

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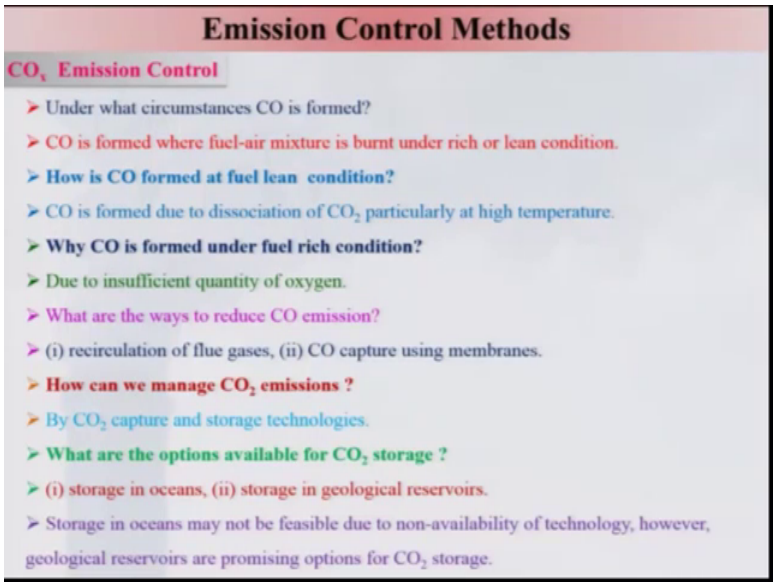

And a CO x emission control, if you look at like a question arises under what circumstances the methane, the carbon monoxide CO is formed. CO is formed where the fuel air mixture is burnt either the under rich or all the lean condition.

Of course if it is a rich condition one can expect CO, but under the lean condition question arises how it is formed. The CO is formed due to dissociation of carbon dioxide particularly at high temperature. And then question arises why CO is formed under the fuel rich condition, because of that the oxygen will be deficient. And therefore, the carbon monoxide will be formed along with the carbon dioxide as the carbon monoxide is not really converted into carbon dioxide.

And what are the ways to reduce carbon monoxide emission? There are two ways one can think of, one is recirculation of flue gases such that the carbon monoxide at the exit of the combustion product again will be reused, such that the carbon monoxide is converted into carbon dioxide. Another way is to capture the carbon monoxide from the product gases using the membrane technology.

How can we manage to control the CO 2 emission? By carbon dioxide capture and storage technologies. And what are the options available for carbon dioxide storage? One is of course, the storage in oceans and other is storage in geological reservoirs, like your coal reservoirs we are having coal mines, the oil mines, oil reservoirs and also gas reservoirs.

So, those places can be used. Storage in ocean may not be feasible in recent time particularly due to the non availability of appropriate technology. However, the geological reservoirs are promising option for carbon dioxide storage, carbon monoxide storage, carbon dioxide storage, because of fact that the technologies available and also the spaces like your mines, reservoirs which are already being used and it is empty. And, particularly for the coal and also the for oil reservoirs which are already being used by the people and those spaces can be used to store the carbon dioxide.

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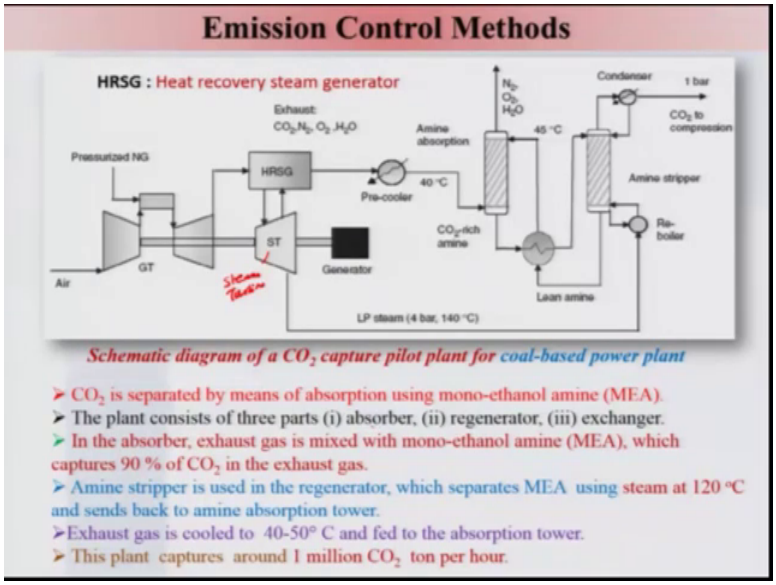

But however, there will be leakage problem and one has to do that. Now, let us look at how we can really capture the carbon dioxide and there are several ways, but we are now going to see how to do that particularly in the coal based power plant. And, this is a schematic which is being shown and this is a combined power cycle: one is the gas turbine type of cycle is there, there is a steam turbine, this is a steam turbine. And in this gas what is being is that in the heat recovery steam generators in from which you can get the exhaust gas CO 2 and N 2 O 2 and water.

And, this gas has to be pre cooled around 40 degree Celsius to 50 degree Celsius; one can capture these carbon dioxide is basically using the mono ethanol amines. And this plant is having the three parts one is absorber, this is basically amine absorber and other is re generator or amine steeper you can say and there is a exchanger.

And once this as I told earlier the pre cooled the exhaust gas will be passing through this amine carbon dioxide will be absorbed and with the due to the presence of mono ethanol amines. And which air captures around 90 percent of carbon dioxide and the exhaust gas and this carbon dioxide rich amine will be passing through this chamber going into the amine steeper's, where the steam is being used at 120 degree Celsius.

Such that this amine will be separated out from the carbon dioxide and it can goes back to the again heated and put into the amine absorber. So, that you will be using less amount of recycling will be occurring here and then the exhaust gas is cooled in a condenser to 40 to 45 degree. And, fed to the absorption tower or and also there it can be carbon dioxide can be removed from here such that carbon dioxide will compress and can be used. And this plant captures around 1 million carbon dioxide ton per hour and which is a quite huge and this is of course, is one of them but there is several ways of doing the similar thing.

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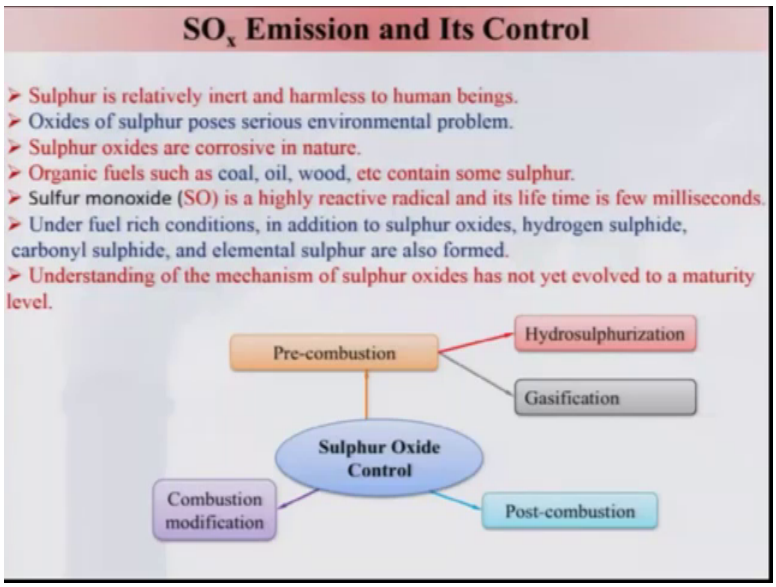

And that has been developed by various companies and let us now, look at the SO x emission and its control. Sulphur is relatively inert and harmless to the human being. However, the oxides of sulphur poses serious environment problems. As it is corrosive in nature and organic fuels such as coal, oil and wood contains certain amount of sulphur, fortunately Indian coal is not having large amount of sulphur. And but however, the Chinese coals are having large amount of sulphur by which we may be affected and

sulphur monoxide is highly reactive radical as its lifetime is a few milliseconds. And under fuel rich condition in addition to sulphur oxide the hydrogen sulphide, carbonyl sulphide, elemental sulphur are also formed.

And this also has to be removed from the gas before it is letting out to the atmosphere and understanding mechanism of sulphur oxide has not yet evolved to a maturity level. However, we need to look at various ways of controlling sulphur oxides from the combustion system. There are three ways of doing that, one is pre combustion and other is the combustion modification and other is the third is the post combustion.

And these three methods are not only for the SO x emission and its control, but it can be valid for NO x emission control CO x emission control any control method as a matter of fact. So, let us look at the pre combustion method, hydrosulphurization is one of them other is the gasification both of them we will look at briefly.

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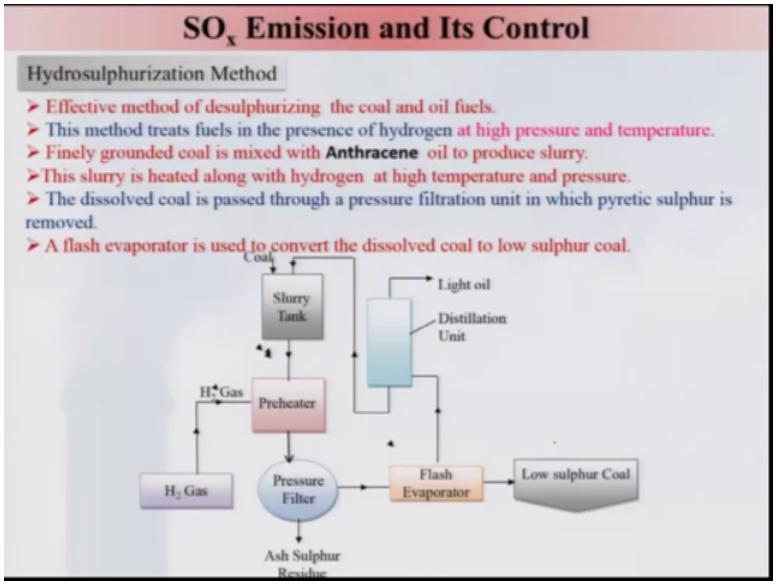

This is one of the effective method of desulpherizing coal and oil fuels and this method treats fuel in presence of hydrogen at high pressure and temperature. Now, let us look at a schematic of a typical hydrosulphurization method in which the finely grounded coal is mixed with anthracene oil producers slurry and this is your slurry tank. And, where the coal is mixed with finely grounded coal is mixed with anthracene oil and this slurry is heated along with the hydrogen gas which is passing through this at a high temperature

and pressure. And such that and then this slurry along with hydrogen will be passing through the pressure filter, where the ash sulphur and residue will be separated out.

And then this gas will go to the flash evaporator and basically it will pass through the distillation where the light oil will be going out, but this anthracene oil will be going back again to the slurry tank. And, thus low sulphur coal can be really separated out of this unit cell that it can be reused also. So, by these one can then flash evaporator is used to as I told flash evaporator is used to convert the dissolved coal to the low sulphur coal. And, this is a method which is being used for hydro for separating the sulphur from the coal itself before being used in the power plant.

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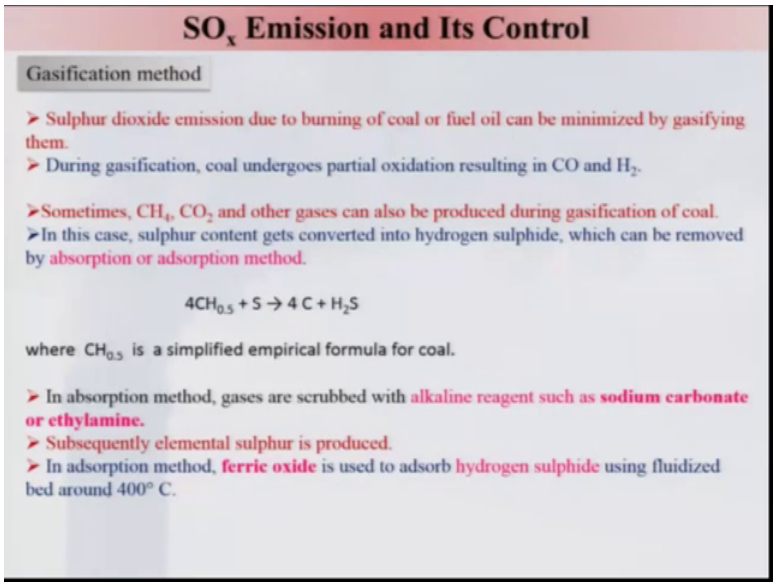

Another method is gasification method sulphur dioxide emission due to the burning of coal and fuel can be minimised by gasifying them before really use that gas. And of course, in nowadays it is being popular, because a lot of emission can be reduced particularly the constituents which causes the emission during the combustion.

So, during gasification coal undergoes partial oxidation resulting in CO and hydrogen and gaseous fuel is easy to handle and that is why nowadays the integrated gasification is being popular and being developed across the globe. Sometimes the methane carbon dioxide and other gases can also be produced during the gasification of coal. In this case sulphur content gets converted to hydrogen sulphide which can be removed by absorption or the adsorption method. And, if you look at this CH 0.5 is basically

simplified empirical formula for coal, 4 moles of coal is reacting with sulphur is getting into 4 carbon plus hydrogen sulphide.

And in absorption method gases are scrubbed with alkaline reagent such a sodium carbonate or ethylamine such that the hydrogen sulphide and other constituent can be removed easily. Subsequently the elemental sulphur is produced and in adsorption method ferric oxide used to absorb the hydrogen sulphide using the fluidized bed which is operated around 400 degree Celsius.

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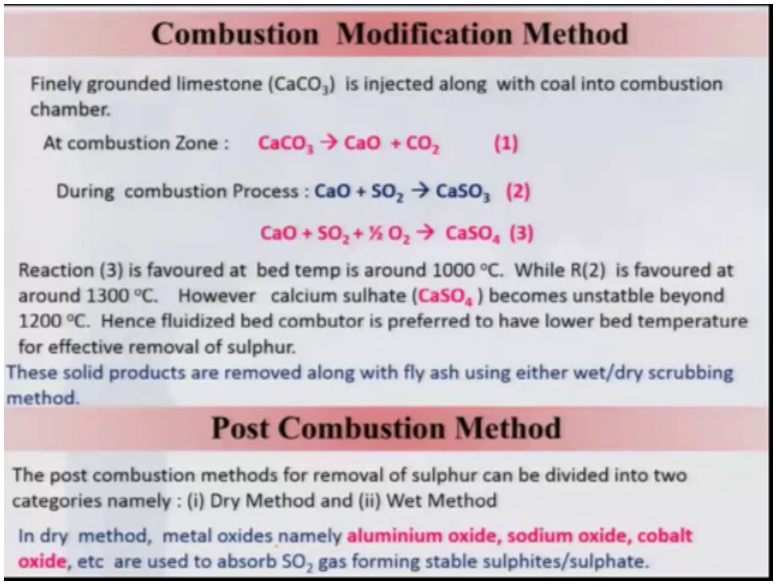

So, let us now look at the combustion modification method; generally the finely grounded lime stones is injected along with the coal into the combustion chamber. And at combustion zone the calcium carbonate is decomposed into calcium oxide and carbon dioxide and during the combustion process the calcium oxide is reacting with the sulphur dioxide forming the product of calcium sulphide and of course, this occurs at a higher temperature. And, this also calcium oxide can be reacting with sulphur dioxide in the presence of oxygen forming the calcium sulphate. So, generally the reaction 3 is favoured at bed temperature around 1000 degree Celsius whereas, the reaction 2 is favour at around 1300 degree Celsius.

However, calcium sulphate become unstable beyond 1200 degree Celsius and of course, keep in mind that the combustion temperature during the of coal, will be the bed temperature of the coal combustion will be around 1500 this thing degree Celsius.

Therefore, nowadays people are preferring the fluidized bed combustion to separate the particularly for coal with sulphur as it can operate at a lower bed temperature, which is effective for removal of sulphur.

And, these solid products are removed along with fly ash using either wet or dry scrubbing method which is quite standard and let us look at post combustion method. The post combustion methods for removal of sulphur can be divided into two categories, namely the dry method and other is the wet method. In the dry method the metal oxides namely aluminium oxide, sodium oxide, cobalt oxide etcetera are used to absorb the CO gas forming stable sulphide and sulphate which can be removed easily by the wet or dry scrubbing.

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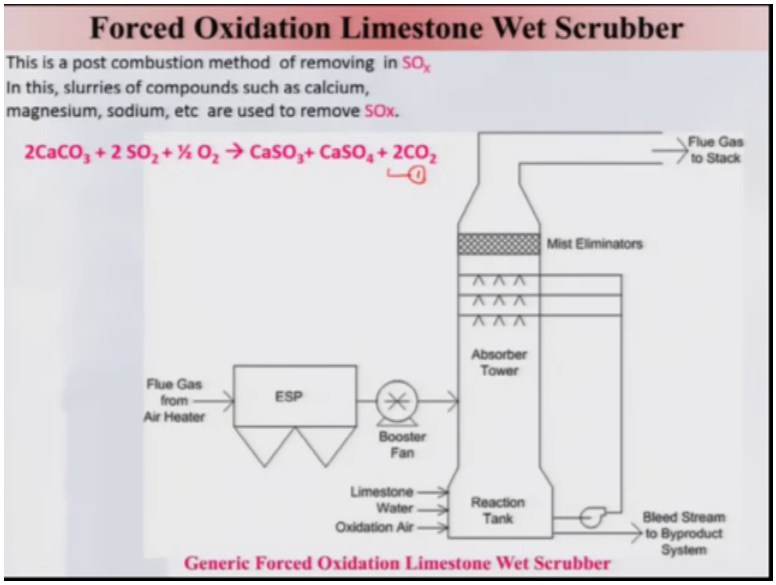

And let us look at now the forced oxidation lime stone wet scrubbers and this is basically a post combustion method for removing the SO x, in this the slurries compounds such as calcium, magnesium, sodium etcetera are used to remove the SO x. Let us look at a typical setup for the forced oxidation limestone wets scrubbers.

And of course, this is this will not be that so simple, but in this case the flue gas from the air it is passed through ESP that is electrostatic precipitates, then it will be passed to the boosted fans such that the pressure will increase. And, it will go pass through the absorber tower in which of course, the limestone finally, a powdered limestone with the water and also the slurries compounds are being fed into here which is not shown and

there might be some oxidative, there might be some supply of air for oxidation where reaction will be going on.

And these will be basically some of these things will be going and then what you can pass through certain waters. And, then sprinkle on it in such that this will be mixed with that and then some reaction will be going on and then it will be coming down and then you will separate it out. And, if you look at the two moles of calcium carbonate will be reacting to moles of SO 2 plus in the presence of oxygen going to the calcium sulphide and calcium sulphate and 2 moles of carbon dioxide. Keep in mind that this I have given a one equation, but there will be several equations which will be occurring and this is just a representery of overall reaction what is will be going on.

And, then only once the sulphur being removed in terms of in form of calcium sulphide and calcium sulphate; this gas will be cleaned out of sulphur SO x and then flue gas will be passing into the atmosphere. So, this is the method which is already implemented in the power plants and with this we will be stop over here and then we will discuss about basically the NO x method in the next lecture.

Thank you very much.