Clean Coal Technology

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Hi, I am Professor Barun kumar Nandi, welcoming you to the NPTEL online certification course on clean coal technology. In module 7, we will discuss various methods used in industrial practice for emission control from combustion utilities. So, in this lecture 5, I will be discussing the removal of dust particles from coal combustion utilities using settling chamber or settling tank methods. Typically, a settling tank is used for the removal of larger-sized dust particles or ash particles with low temperatures. So, in this removal method, we can typically remove larger-sized dust particles or fly ash particles that have low temperatures, meaning the temperature is not on the higher side, like 500 or 700 degrees Celsius, but rather in the range of atmospheric temperature or around 100 degrees Celsius or nearby. Typically, in this method, water is used to improve or increase the mass or weight of the ash particles. As water is used, the ash particles gain weight. Their mass increases, so their weight or gravitational force increases, and they settle down more quickly. Comparatively, we also have similar methods available using dry methods, like a dry chamber, which typically has lower efficiency. So, if we want high efficiency, in most cases, water is used as it is a cheap and readily available liquid found everywhere. And if water has any reactivity or other issues that prevent its use in dust particle removal, in such cases, a dry chamber is used. Alternatively, we can use any other liquid or solvent that can replace water but is still cheap and industrially feasible.

Another advantage of this method, particularly the wet method, is that we can add other chemicals. Other chemicals, meaning those that can be added to water to remove different types of gaseous pollutants if required. Along with the flue gas, there can be other toxic gases, heavy metals, or similar materials or pollutants present. And if we want to remove all of them in one piece of equipment, like if it contains sulfur dioxide compounds, we can add water. If it has nitrogen, H2S, or ammonia-type compounds, we can add suitable chemicals that will capture them. This ammonia or sulfur dioxide or any other chemicals along with the water. So that can be like an absorption chamber also, so in this settling tank or settling chamber it can have dual activity like capture of dust particle by simply physical action as well as some of the chemical reactions also can be there by absorption of gases as well as any other pollutants in water or in

the liquid phase. So, if we want to remove any other gaseous pollutants which may be present or maybe there is some mercury or other heavy metals is there and if we know that this particular Chemical can capture or reduce the mercury emission or lead emission from the flue gas. Those type of chemicals also can be added along with this water so that we can simultaneously capture ash particle as well as we can reduce the any other pollutant released through the flue gas. Typically, in terms of efficiency, here efficiency is bigger or higher if we use the bigger size ash particles, whereas if the particles are in the smaller size, then typically efficiency is higher on the lower side. So, in such case we may need some very good water sprinkler or water spraying. So that we can modify some of the surface activities or surface phenomena in the dust particles and still we can capture them and after this water spraying whatever the ash particles or other chemicals which we are trapping, they will be captured in the water phase or in the liquid slurry phase through the settling agent. So, if we see a simple example like a water stabbing system, so here if dust particles are entered here we allow this water to be sprayed here. So, in such case there is a very good contact between water and dust particles they get wet So, in the next chamber, this clean gas will go out and whatever the liquid is there, they will trap all the pollutants including dust particles and any other chemicals, harmful chemicals, those can be captured by this liquid phase, so the slurry or water. If we see the dry methods like in a dried settling tank how these pollutants can be removed this is the example for or methods for the use of dust particles in the drying chamber or dry method using the settling chamber method. So typically, the dust particles are entered through this line. So, if these dust particles are entered through this line through this pipeline so when they enter here so if we see in a common phenomenon. Any chamber dust particle goes there it will have towards this the gravity force whereas the in this way it will give the get the momentum. So in between these two force this momentum force which will take this particle to this direction and gravity force which will take this particle to this direction. So, in this way what will happen that the heavier particle which has higher amount of gravity force that means if mg value is on the higher side compared to this momentum direction or momentum force. So, in such case this particle will get settled down and after settling down they small particles or the air with zero dust particles depending on the particle size. So, they will be released or we can say the clean air will go to this the exit path. So, what will happen here most of the bigger size dust particle they will get settled down in this chamber like due to action of this force, so most of the dust particle will get settled down. So, we will get almost clean air or air containing smaller size dust particles which doesn't have adequate amount of gravity force. rather their normal velocity force will take them to take out of the system.

So, what we can get is that heavy particles drop out due to reduced velocity, and we can even modify this particular chamber into different shapes so that the dust particles get adequate residence time to precipitate or fall down. So, this will be the different design or different modifications of the simple settling tank chamber. So, if we see that the same chamber can be done in a continuous way, maybe two or three settling chambers in series, like if we say the gas inlet, it will pass through the first settling chamber, then it will again pass through a second settling chamber, a third settling chamber, and a fourth settling chamber. So, in this way, they can be connected. as per our requirement in a continuous mode so that we can get the gas outlet, which will have almost less particle loading or almost clean air. So, if we see the advantage and disadvantage of this method, it is that in this method, typically, we can remove the bigger size particles, and if we want to improve the efficiency, we have to increase the mass of these dust particles, so those are done typically. by using the addition of water, which is known as the wet scrubbing method. So, if we add some amount of water to the dust particles and if the dust particles get wet by this water, the overall gravitational force increases, and that can be easily removed.

As their settling velocity will be on the higher side, their residence time will be less. So typically, wet scrubbers are used for the removal of dust particles having a size of 0.2 mm or higher. So, in this method. Typically, we can remove the dust particles having a bigger size, that is 0.2 mm or 200 micrometers. So, this method is used exclusively for very big-sized dust particle removal.

If the dust particle sizes are in the bigger range. they can be efficiently removed. As here, only the gravitational force and velocity force are there; there are no other forces which can improve the efficiency. So, overall, by this settling tank method or settling chamber method, we can remove only the bigger-sized dust particles. Its cover works by spraying a stream of fine liquid droplets on the incoming stream so if we add water or if we go for the wet scrubbing method they typically spray water or any suitable liquid droplets on the incoming stream and these droplets increase the mass as it gets absorbed by the water so its droplets capture the dust particles and this liquid is subsequently removed for treatment. So, after this whatever the liquid will be there that liquid will contains all the dust particles. So that liquid or water has to be treated or has to be purified before discharges to the nearby water bodies. so that type of purification system has to be there and they are consisting of rectangular or circular chamber in which nozzles are mounted. There are the different designs available, which have different type of design may be in a rectangular tank or in a circular chamber and which contains

different type of water nozzles or water spraying activity atomizer system. Everything can be there by which water is effectively sprayed over the dust particle. The nozzles spray a stream of droplets on the incoming gas stream and that droplets contact with the particulate matter and as the particulate matter gets absorbed or dissolved, they will get wet. The droplet size will get be optimized like up to what droplet size we can use. That means whatever the droplet size of the water molecules is the water particles are there. They has to be optimized that if we make very, very fine size so they may not be efficient to capture the dust particles and they may just go along with the air stream. Whereas if we make very big droplets so they may not have the higher particle correction efficiency and they may not have the adequate residence time to get adsorbed or so that these droplets can absorb the dust particles. So there has to be in the medium size in the optimized not very fine size as well as not stops any bigger size and typically if we go for the smaller droplet size they give the better cleaning but not to the very fine size that they will just be acting like a normal moisture and it will go. So, it has to be optimized and it has to be optimized for different type of dust particles because if the dust particles composition or chemical composition of the fly ash changes. So, they can have different amount of surface activity, their surface tension may be higher or lower as these water droplets is get adsorbed over these dust particles. So, their surface so that dust particles would get easily wet. So, if any dust particle has chemical compositions such that those dust particle will not get wet easily so then it needs higher amount of water spray and other things. So overall this droplet size has to be optimized based on the surface tension and other surface properties of the ash particles as well as between the contact angle difference and others with the water droplets as well as the dust particles and sprayed polluted spray is collected at the bottoms particles are settled out otherwise to be removed from the liquid and whatever the liquid is there it has to be recycled so that the water consumption is not on very higher side and as the role of this liquid is only to improve the mass or weight of the dust particles. Typically, after removal of dust particles which is settled down, this same water can be recycled in the plant. But if the temperature is on the higher side, we have to regularly add fresh water as a make-up water because some of the water can go vaporized along with the flue gas if the temperature is on the higher side.

This is one of the pictures or how this settling chamber in the spray is acted upon. Like if we say from this side, dirty gas is inlet here. So, this dirty gas enters and in this pipe particularly, if we see this section, it has a very, very small atomizer. So, through which the water spray will be present. So, water is inlet from this side, water will enter from this side and it will

spray the water in all directions at a very small droplet size. So, at this very small droplet size, as this water is sprayed throughout this entire zone. So whatever gases go there, they will enter here and they will pass through this water spray. At least two or three cycles they will pass, and after that, they will get out. And by this process, whatever water droplets are there, they get in contact with the entire gaseous stream. So, the entire gaseous stream, whatever is there, will get in contact with water. Dust particles will get wet and they will settle down. After that, this used water comes out through this water tank, whereas the clean water goes to this output point, which will be almost free from other pollutants. Now in this case, as there is some contact time or absorption time through this length, so we can add different types of chemicals along with this water depending on the chemical reactivity in the absorption process. So, absorption process we can add different chemicals which can trap sulfur dioxide and nitrogen or any other maybe some chlorine rich pollutants, maybe some unburned hydrocarbons or hydrocarbon vapors which can get dissolved in water so or any other suitable adsorbent or liquid we may add through this water, which will efficiently remove some of the gaseous pollutants also. So, this is the advantage of this method that along with this water spray in the water if we add some smaller dose of any other chemicals like if flying a flow gas have some acidic gases If it has some acidic gases, we can add some even some basic compound base or alkali in the solution in this water. So, if we add some alkali like if we add some calcium or sodium oxides, potassium oxides, so they can easily react with the sulfur compounds present. They can get trapped the sulfur compounds.

If there is some ammonia is present, we can add some little bit HCL or other chemicals which can easily react with this ammonia. So effectively depending on the flue gas composition and if we want to remove particularly some pollutant gases which has not been adsorbed in previous units or which has not get trapped in the previous units and if its permissible limit is higher that means whatever the flow gas is being going out it has higher number of gases and which is exceeding the permissible limit. So, in such case along with the water we can add those suitable chemicals which can react and absorb all these harmful gases in the same settling tank. So, if we see the advantage and other aspects of settling tank they can handle high temperature gases but water consumption will be on the higher side like if the any plant doesn't have any suitable heat recovery system before the flue gas. Like flue gas is going out at 300 degrees centigrade, so that that plant doesn't have any good suitable heat recovery system for any reason. Either it is not technically feasible or they have not installed it maybe in the older plants. So, in such case water can be used to capture this dust particle but their water consumption will be on the

higher side because most of the water will be converted to near the steam. So, as this heat will be removed by vaporizing the water. so, their water consumption will be significantly on the higher side these methods can handle Even the high particle loading, like if the dust particle has higher amount of density or higher amount of mass, that means per unit volume of air, there is more number of dust particles are there. So, all the dust particles can be captured by these methods without there is a significant increase in the cost. As we have seen in the other method like bank filter, If the dust particle loading is on the higher side, there needs frequent cleaning.

If dust particle load is on the higher side in the ESP, operating cost as the ionization cost in the electricity consumption is increases. So overall operating cost increased. But in this settling tank method, same amount of water can trap large amount of dust particles. So, without any increase in the operating cost. So, this method can be used even for the dust or air or flue gas which has higher amount of dust particles and if there is any change in the loading fluctuations like dust particles are increasing or decreasing, their percentage is varying in each moment in the flue gas. So that doesn't affect the removal efficiency whether there are only five percent dust particles are there in the air or there are twenty percent dust particles in the flue gas all will have or all will get removed if their particle size is in the range within the range of this settling tank. So, it can handle even there is any change in the loading if there is any change in the load of dust particles it is varied at every moment it doesn't affect any removal efficiency. All the dust particles will be removed if they are within the size range of this settling tank chamber. So, it doesn't affect with the mass percentage of dust particles in the air and even they can handle explosive gases if some of the gases have some explosive compound at their gases are there. So those explosives gases also can be captured or they can also can be purified through this water. So, using this water it will not have any hot or any other temperature activity. So, if these explosive gases are filtered through the bag filter there is a chance of fire or fire hazard because these explosive gases can give explosion and anytime can increase the temperature. So those are typically not suitable for removal using the bag filter but those can be done using the water as this water will reduce the temperature of this flue gas significantly. So, it will have very less risk and it can handle explosive gases and it can have the gas adsorption or absorption system if it has any type of pollutant gases is there which needs to be adsorbed or that means if it has to be removed it can be done by the same unit along with the dust particle removal and even it can handle the corrosive gases if these gases have some corrosive material. So, they can corrode the bag filter they can corrode the electrodes in the ESP and even in some cases they can corrode the cyclone separator metal like if the gases are

reactive with the metal, so in such case cyclone separator lifespan will get decreased. So, in all these materials can be captured by this settling tank method without any damage to the settling tank. So, it can handle even the corrosive gases and effluent scrubbing liquid flows and water pollution problem if we trap all this type of pollutants here. So, whatever the water will be released from this system in such case this water must be purified or it might be treated as per the guideline. So that it does not pollute the nearby environment as by this method if we summarize whatever this settling tank is doing is that that it is effectively transferring the pollutant from the flow gas to the water body. So, by this method effectively any pollutant is present in the air so it is now transferred to the water.

So earlier, it was the air pollution issue. Now it is the water pollution issue. So, we have to handle the water pollution issue in the plant by a suitable method. The same thing in a modified design is there, which is the venturi scrubber. So, in this case, the dirty gas and liquid are inlet here, so they can have very good contact at this particular zone. This high-velocity air goes through this unit, and there is some moisture eliminator section so that any moisture doesn't go out. They can go out, and the water can So this is another design of the similar equipment. So if we see, there are many designs possible. It can be a wet scrubber, a dry scrubber, a venturi scrubber, or many other designs of this equipment can be possible. They can be made. as per the requirement, but the overall principle will be in a similar range or similar type. So, depending on the requirement, many industrial equipment is there. In the regular textbook, we can get many other methods also. Venturi scrubber is only one of them. So, in this method also, we can remove the dust particles or in this equipment, we can remove the dust particles only. That is the main difference between the different types of equipment that is their contact time or how these gases and dust particles are mixed or they get contact with the water. So that is the only difference. So, if we need some high contact area or if we need some smaller contact area, if we need very good collection efficiency for moisture or if we want to trap different types of pollutant gases, this design can be changed or fine-tuned as per the requirement. So, in this venturi scrubber, at the inlet throat, liquid at low pressure is added to the gas stream, and efficiency is in the range of 95% for particles larger than 0.2 mm. So, these have a similar type of efficiency, but here we press the high-pressure liquid.

In our previous design, we were only allowing liquid to flow without having any major pressure. That means it was at normal atmospheric pressure or one bar pressure. But in such cases, we use some pressurized water, a little bit. So, it can allow efficient contact between the

liquid and the gases so that all the pollutants get adequate contact time for getting captured or trapped in the water system.

So, if we summarize here, only the bigger-sized ash particles can be removed. If we see the size of the dust particles, they are in the range of 0.2 mm. Whether this dust particle size is still in the bigger size, whereas in coal combustion, if pulverized coal combustion is used, their dust particle size is around 10 mm. micrometer or less, but if it is converted there, it is around 200 micrometers. So, dust particles removed by this method are in the bigger size, which typically happens in the case of fluidized bed combustors where bigger-sized coal is used.

But if you see the pulverized coal combustor, as smaller-sized coal is used, their dust particle sizes are in the range of 10 microns. It is not so efficient for the removal of dust particles, but this method can be efficient if we want to remove any type of SOX, NOX, or other gases. So, there are two different applications for the same method. Like in this method, we can remove the dust particles, as well as the harmful gases. So, in the pulverized combustion units, this similar unit can be used to trap the pollutant gases from the flue gas, not for the removal of dust particles.

So in dry settling strength typically has the lower efficiency it doesn't have any water consumption but in wet or water spread method water consumption will be on the higher side and it will be significantly high if there is the temperature is significantly high like 200 or 300 degree centigrade water consumption will be less if it is the atmospheric or below 100 degree centigrade temperature and other gases also can be removed in water And we can add suitable chemicals to remove the other gases simultaneously. And if we see the cost of this system, typically this installation cost is almost zero or very minimum. Only we need one tank design and water spraying arrangement and water collection arrangement. So overall, if we see the installation cost is very, very low compared to the ESP is significantly higher, bag filter is only on the higher side and still in a cyclone separator we also need one type of water pump that gaseous compressor and other. So, it has some installation cost. But if we see in terms of installation cost, it will be very less or minimum for the settling tank. but it can have higher operating cost as the cost of water will be significantly high we have always has to supply water to this unit and this water also needs to be treated for the removal of pollutant and if this water contains some of the acids or base so they can corrode the pipelines and others so it can have some amount of maintenance cost as well so if we see the settling chamber it has very less installation cost but it can have higher amount of operating cost as well as maintenance cost.

So, if we conclude from all the different classes, in this module from lecture 1 to lecture 5 so if we see in most of the cases cyclone separator is very efficient for bigger size particles up to 10 microns or like that size ESP and bag filter they can have 100 efficiencies for all type of particles or dust particles but they have higher operating and installation cost. ESP efficiency changes with changes ash composition as the dust particle composition if the elemental composition is changes they can have resistivity or to the getting charged, so whether they will easily ionize or easily not capture the charge it can affect the particle collection efficiency. So, with the Change of composition of the fly ash or elemental composition of the fly ash, ESP efficiency can be different or can be varied. But if the mass of the dust particle is varied, in such case, ESP, bag filter and other can have some change in the efficiency. But if the composition changes, like if the source of the coal changes or source of the fly ash gets changes, ESP can have minor variation in its efficiency.

Whereas the settling tank and water spray method are suitable for very, very big size particles around 200-micron size. for 0.2 millimeter. So, they are mostly suitable for the units where bigger size coal particles are burned like FBC based unit or any fuel bed combustion-based units but not suitable for the pulverized combustion-based units. Combination of two and three equipments are required. So, if we see that some of the equipments like cyclone separator and settling tank they are very much efficient in removal of bigger size particles whereas ESP and bag filter. They can remove all the materials all the dust particles from the flue gas but they have higher operating cost. So if we want to optimize or reduce the operating cost we have to use two three different dust particle correction method Considering the particle size, operating cost as well as the pressure drop in the unit if there is a significant amount of pressure drop is also there, like in the case of bag filter, main combustion units efficiency can be modified or it can be different as if these gases pollutant gases are not removed efficiently that can change the kinetics chemical reaction, kinetics during the coal combustion, as concentration of CO_2 can be increased if there is significant pressure drop.

Pressure drop increase means in the inlet size their pressure will get continuously increased. So, concentration of CO_2, H_2O will get increased which can impact the equilibrium, chemical equilibrium which is happening during the combustion reaction. So, we have to also take care about the pressure drop. their particular removal efficiency, operating cost as well as installation cost. So, we have to use combination of two or three different equipments can be used as well as when we want to consider about the any other gaseous materials also to be removed. If it has smaller number of gases like Sulphur dioxides and others, those also can be

removed by this method. So, we should consider a combination of two, three different methods to efficiently remove the dust particles or all the fly ash particles from the flue gas and feed size of coal ash particle size must be continuously monitored for the efficient removal of ash. If there is any change in the feed particle size like as we know that pulverized combustion means it is 80 percent particle passes through the 72 microns but if this is not 80 percent passes if maybe the 50 percent passes that means average particle size will be increased in the combustion units if average particle size is increased. So, dust particle size will also get increased, so in such case operating cost and efficiency can be changed similarly if the feed coal size has all the fines particles that means all the not 80 100 particles are below 72 microns or 100 particles are below 50 microns like if there is some any case of over grinding in the system. So, in case of over grinding also generated dust particles will be very finer size. So in such case cyclone separator may not be efficient or that may not do any job and in such case, all the load of the dust particle will goes to the next unit like ESP or that filter so we have to always monitor this feed coal particle size which is being charged to the combustor, what is the particle size of ash is coming out and accordingly we have to monitor or modify the system parameters to efficiently remove all the ash particles from the system. So overall if we see all these four or five equipments can be efficiently used by continuously monitoring the feed size, ash particles, ash particle composition etc. if we continuously monitor them then we can efficiently remove all this ash particles but if we fix with a standard design that one design is there which was made of five years back and by that side that today the properties of coal has been varied mineral matter composition of the coal has been modified significantly, source of coal has been changed we are using some biomass particles in the biomass in the combustor. So, all they can have difference in the ash particle size, ash properties which can affect the dust particle correction efficiency in the system. So on a regular basis on frequent basis, we have to monitor all these parameters and we have to fine tune our particulate matter, removal system for efficient removal of ash particles and for efficient utilization of coal in different combustion utilities This is the reference book that is the environmental engineering textbook which can be used as a very good textbook as well as reference book along with any of the coal combustion and other textbooks. These very good textbooks covering all aspects of pollution control from gaseous pollutants as well as the water treatments etc. So, you can follow this textbook for these particular chapters where environmental pollution is discussed in coal combustion utilities.

Thank you