Waste to energy conversion

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Lecture – 07
Incineration – 1

Good morning everyone. I welcome you all to this module Incineration. In the previous modules on introductions and characterization of wastes we have come to know about different options available for energy conversions and its characteristics. Basically, for energy conversion thermal biological and chemical routes are used now you will start discussion on these routes one by one and the beginning we will start with incineration.

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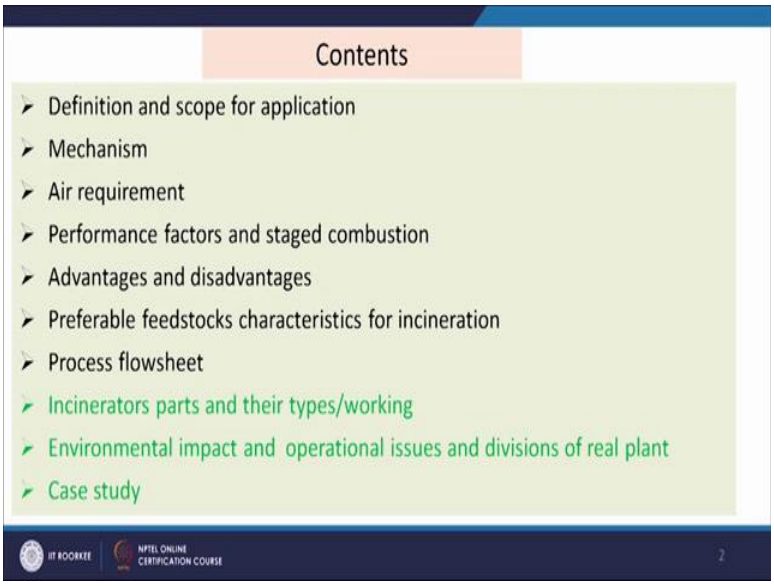

So, this incineration is one of the important thermal routes for energy conversion the others 2 important routes are gasification and pyrolysis.

We will divide this module incineration into 2 part and in the first part, we will see the definition and the scope for application of incineration, mechanism of incineration, air requirement, performance factors and staged combustion, advantages and disadvantages, preferable feedstocks characteristics for incineration and process flow sheet. In the second part, we will discuss on incineration, the types; different types of incinerators and their parts and their working principles environmental impact and operational issues and divisions of real plant and we will also show some case study.

So, in this part let us see what incineration is. So, incineration is a waste treatment process that involves the combustion of organic substances content in waste materials should you define incineration we have got another term combustion which is very synonyms to it that combustion is the sequence of exothermic chemical reactions between substrates and an oxidant which accompany the production of heat and conversion of chemical species.

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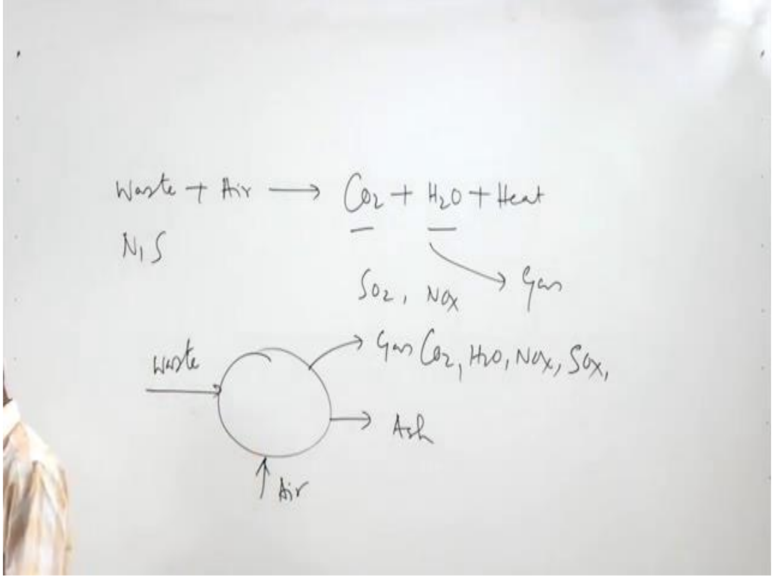

So, if we take waste and air or oxygen it will give us CO2; water and heat now this CO2, H2O will be in gas form, if waste contains nitrogen sulphur waste, we will get here SO2 we will get NOX.

So, for the reactions we need some system that is called incinerator. So, in incinerator we will bit waste we will put waste. So, waste part of the waste the organic part of the waste we will take part in this reaction and it will give us gas that will contain CO2, H2O, NOX and your SOX if nitrogen and sulphur is present in it and the rest will give us residual or ash and for this we need to provide air or oxidant we need to provide air and oxidant. So, what is the advantage of this we are able to reduce the volume of this waste by this operation 2 ash.

So, if you think about the waste management the cost for waste management is reduced the second is the gas which we are getting here this is at high temperature this is at high temperature. So, this high temperature gas can be utilized for the production of steam and there after electricity or can be used in gas turbine for electricity production or this can be used for any heat application. So, this is the basics of incineration process. Now let us see how the combustion takes place if we put one material or waste in contact with oxygen then it is not compulsory that there will be combustion and thyrring until we can provide a certain temperature.

So, for the combustion of a material oxygen as well as temperature is required and this temperature is normally raised by the burning of some liquid fuels or gas fuels. So, liquid and gas initially reacts with oxygen and heat is generated due to (Refer Time: 05:57) reaction and that heat helps the waste or biomass or solid particles to be heated.

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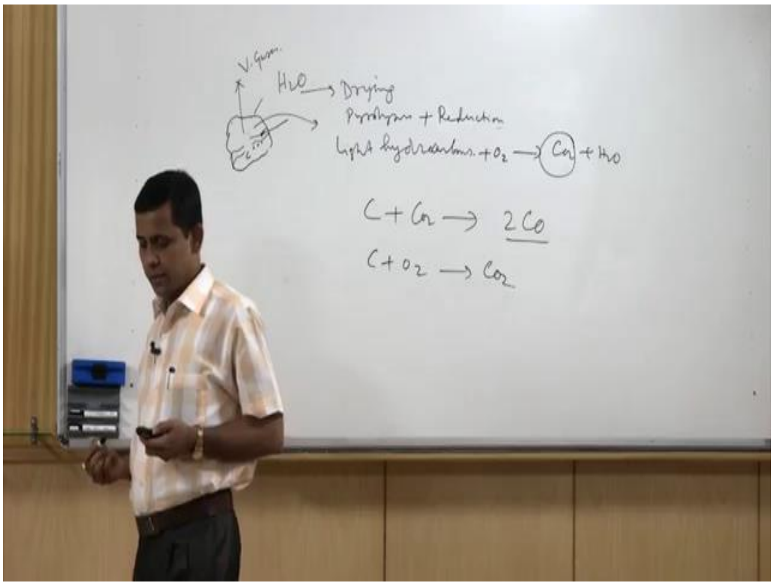

So, the temperature of the solid material increases and due to this at the inside the solid materials the present H2O or moisture is (Refer Time: 06:18) it is evaporated. So, that is called drying. So, drying takes place first once the drying takes place due to increase in temperature further increase helps to remove the volatile gases volatile gases present inside the pores and. So, the porosity of these particles increases porosity of these particles increases.

So, once the porosity increases the air enters through it reacts with more particles inside it the materials carbon materials and then char combustion takes place. So, in this process the first part is drying second is the pyrolysis at high temperature the bigger molecules are broken down to smaller once that is called volatile gases. So, volatile gases are formed that is call pyrolysis when the pyrolyzed gas is formed like say example say hydrocarbons light hydrocarbons hydrocarbons those gases further react with oxygen and converted to CO_2 plus H_2O, but this can also happened this CO_2 which is produced by the combustion of this light hydrocarbons that can further react with carbon present inside the waste materials. So, that carbon plus CO_2 will react and give us to CO.

So, this is also possible. So, drying next is pyrolysis and this is reductions this is reduction. So, these are possible and when the excess oxygen more oxygen is there. So, that oxygen will help to further the oxidations of char. So, this is the mechanism for the combustion of solid waste or any biomass or any carbonaceous material now one interesting thing when the particle is coming in contact with the high temperature generated by the burning fuel with time its size decreases with time its size decreases because the core shrinks. So, they which call shrinking core model for the combustion that is well accepted mechanism, so in this process if we want to get complete combustion of solid particles or waste materials then we need to provide certain time here.

We need to provide certain time here we need to attain certain temperature here another point is if this particle size varies somewhere it is smaller somewhere it is bigger. So, the time requirement will be different time requirement will be different. So, there are number of factors which will influence the performance or the efficiency of this combustion process now one thing you have come to know that if we want to complete the combustion get the complete combustion of the material we have to provide excess oxygen because there are some limitations inside it.

So, to overcome those limitations we have to provide excess oxygen now excess oxygen why are it excess means there is something with respect to we will see that this amount is excess and that is that something is nothing, but a stoichiometric requirement. So, stoichiometric requirement of air or oxygen for any waste material will depend upon its composition the carbon hydrogen present in it sulphur if it is present in it.

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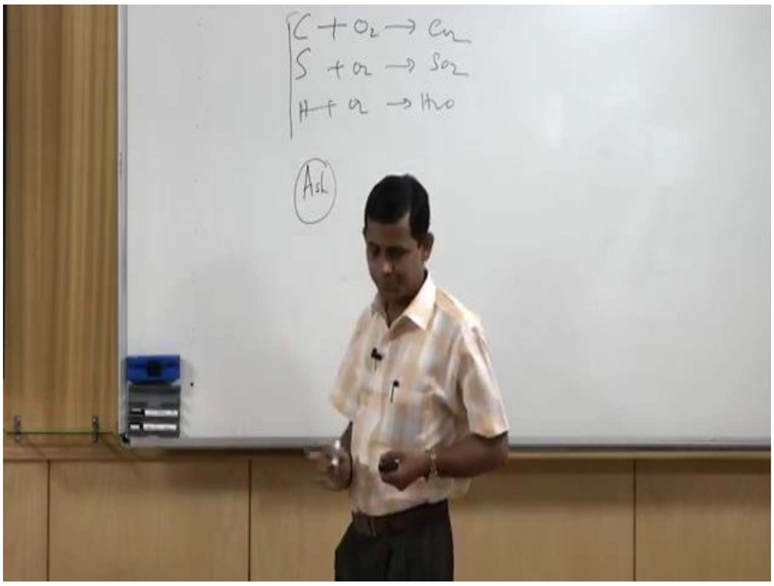

So, those will guide how much stoichiometric oxygen is required for the combustion. So, C plus O that will CO2, S plus O2, SO2 or say H plus O2; H2O, so this reaction is going on complete elemental compositions. So, completely all elements are converted to gas phase. So, that is your comp stoichiometric oxygen requirement and remaining will be ash. So, people try to identify how to calculate the stoichiometric requirement of oxygen.

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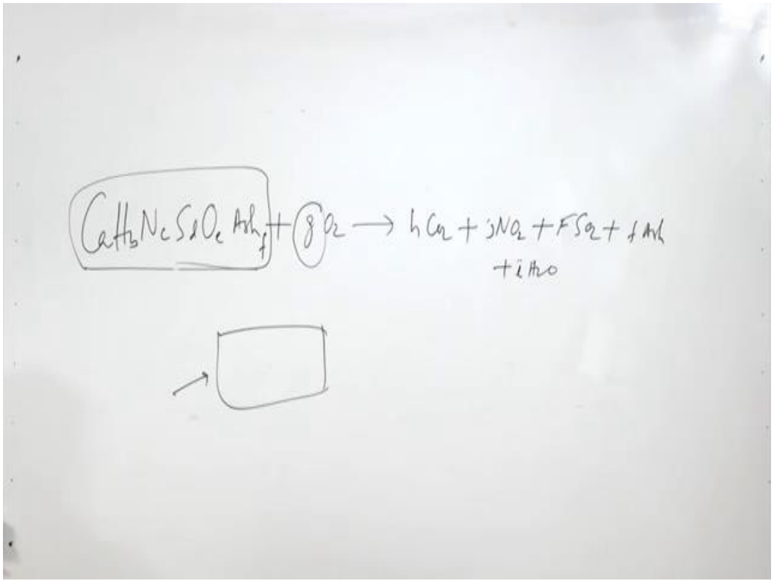

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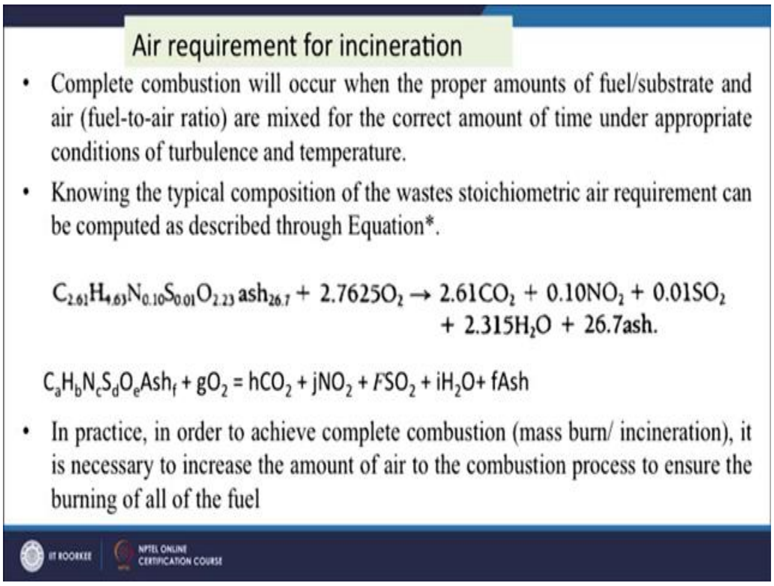

And this is generalized say CaHbNcSdOe and S, this is the molecular formula of the waste or the material that has to be combusted with say this is f and g HO2. So, then it will give us h CO2, NO2 plus SO 2 plus f ash and these will be h this equal to say j and f plus I H2O.

So, these are the product. So, at first to calculate the stoichiometric oxygen requirement we need to get the molecular composition of the material and one typical example is given here that C 2.61 h, 4.63 n, 0.10 a, 0.10 O, 2.23 as 26.7 plus 27; 2.7625 O 2 like this. So, this is one typical example of the stoichiometric requirement of oxygen.

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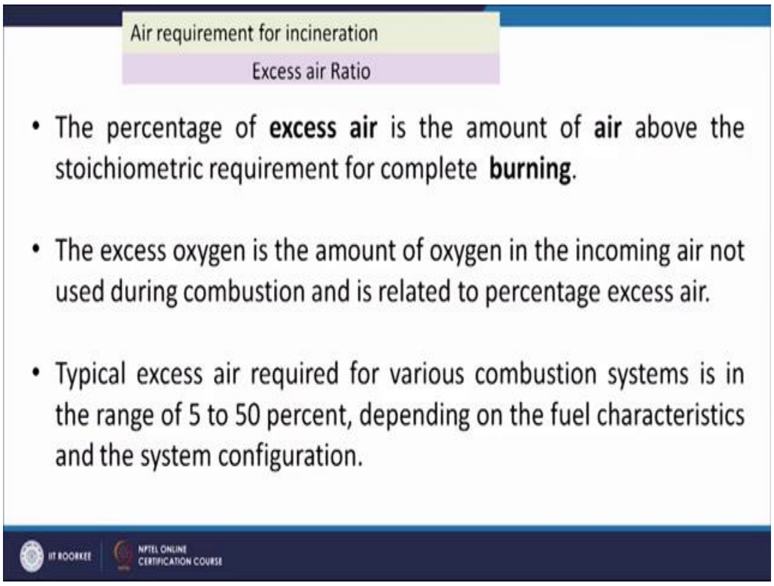

Next excess here how can we calculate excess here; obviously, the amount of oxygen which is supplied into the incinerator with respect to this stoichiometric requirement that will not be used that will not be used.

So, that is excess. So, excess oxygen is the amount of oxygen in the incoming air not used during combustion and it is related to percentage excess air. So, how much excess is required basically for the complete combustions in practice this is 5 to 50 percent. So, 5 to 50 percent excess air or oxygen is required 5 to 50 percents normally these values are used. So, on the basis of these discussions it is clear to ash that the performance of a combustion process we will depend upon 3 Ts that is time temperature and turbulence time typically if it is a fixed way type of combustor or incinerator 45 to 60 minutes in one typical value 45 to 60 minutes.

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So, this time is required for shrinking the course temperature around 980 degree centigrade is required for the combustion purpose and turbulence is required turbulence helps the mixing of the waste and the air or the oxygen. So, that turbulence is also influences the performance of the combustor. So, combustor design will be based on this time temperature and turbulence. Obviously, and different types of incinerations or incinerators can be designed and different performance can be achieved now excess oxygen is one hectare which is essential for complete combustions of the solid waste or any solid material which is having carbon, but; obviously, on operational point of view or I mean on cost point of view this very excess air is not desirable.

So, there is some possibility to control the excess air requirement therefore, to achieve this the minimum excess air or optimum excess air the people tried in the design or the process design part say.

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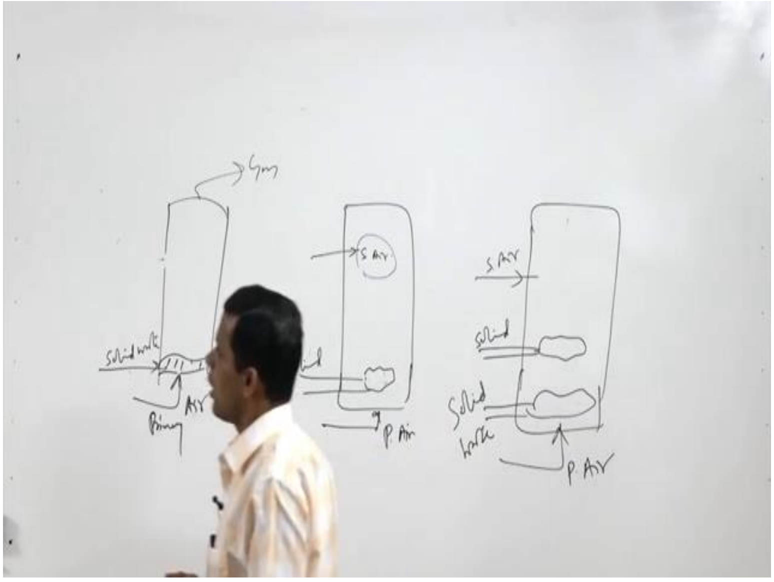

If we have on incinerated, we can feed the fuel or the solid waste and oxygen in different ways. So, some solid waste is feed here. So, you can get oxygen or air and here again secondary air is given. So, primary air primary air solid waste and this is secondary air. So, this air supply can be done in phases solid waste can be put in the furnace or in the incinerator in physics. So, phase wise supply of this waste and air can help to reduce the excess air requirement and by this way we can achieve good mixing which supports and operation at low excess air.

So, excess air lambda less than one point five and by this process also concentrations of unknown pollutants become closure to 0. Now you will see some examples of 2 stage combustions stage combustion. So, first one is convention conventional one. So, here we are putting the solid waste and here we are putting the primary air. So, those will be combustion will be going on and then it will be flu gas or hot gas will go out and we will get ash from it now staging say we are going for air staging. So, air staging means we are putting here solid waste, we are putting here air primary air and then we are putting here secondary air how this process change changes in this case we need excess oxygen very high or more air is required with comparison to stoichiometric ratio.

Here the air requirement will be lesser then this case excess air requirement and the quality will also be good. So, in this case the primary air helps for the drying and pyrolysis and then combustion and this secondary air helps the combustions of the pyrolysized materials the reverse phase materials. So, this is air staging now if we think about fuel staging. So, fuel staging can be achieved like this. So, there is one solid primary air solid waste then we will put another solid waste and we will put air.

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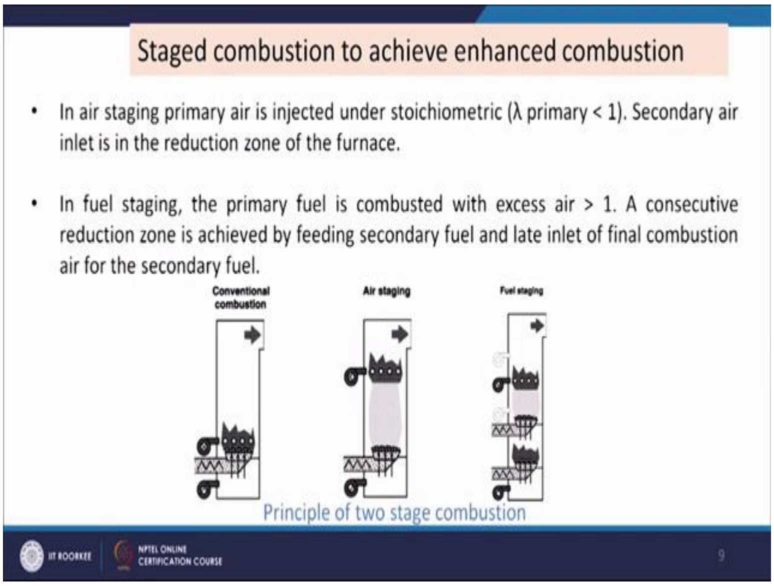

So, in this case how it is different the air staging primary air is injected under stoichiometric. So, this is under stoichiometric la lambda is less this is 1 less than; 1 less than, but here lambda is high. So, it is greater than 1; 1 to 1.5 in between 7. So, this is greater than 1.

So, when it is greater than 1 excess oxygen will be there. So, again we can put some solid waste. So, that can be further oxidized by this excess oxygen and then all reprised or primary combusted materials will be further combusted air to the secondary air. So, these way different approaches have been developed and people tried to optimize the excess air requirement.

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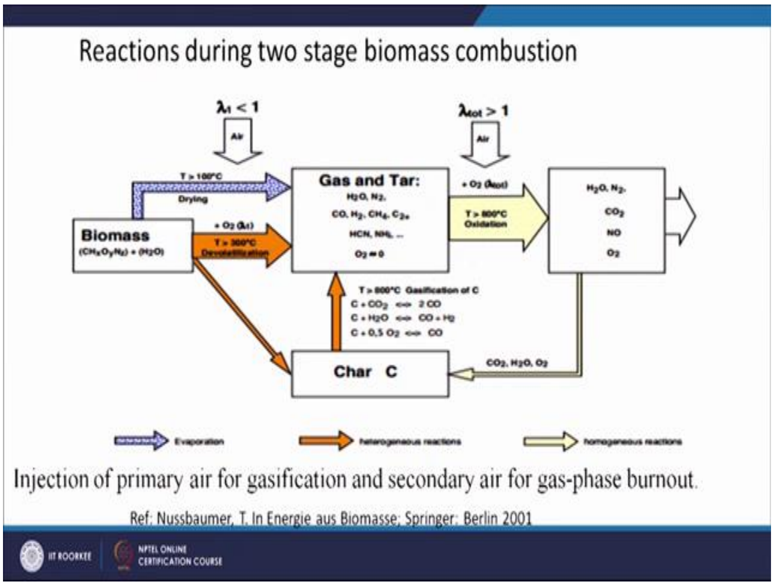

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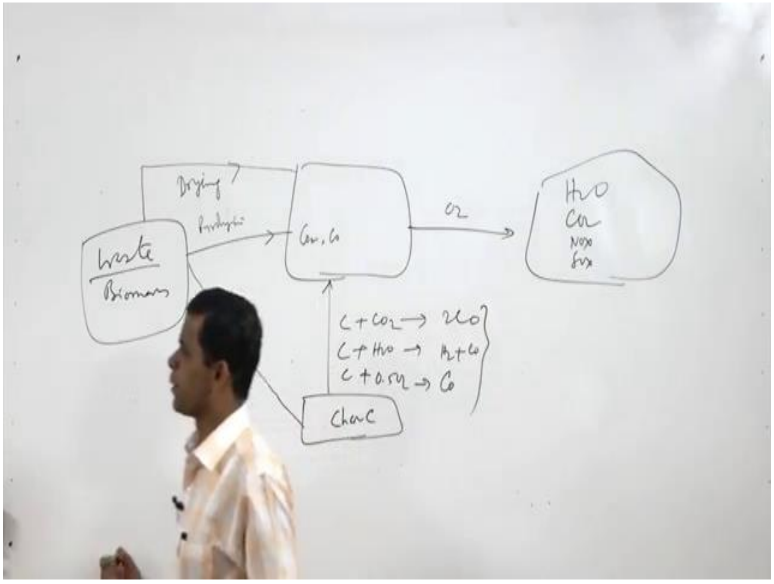

Now, we will see some reactions during 2 stage combustion process from reactions during 2 stage combustion process. So, here we have waste or biomass. So, when will put heat a temperature will be 1; 105 degree centigrade. So, it will give us moisture temperature is higher pyrolysis will go.

So, this is drying pyrolysis and then further oxygen is also present. So, that that can also give char and by heating char will form and that char will further be oxidized to this things. So, this is char carbon, this is pyrolysis. So, pyrolysis will; obviously, give the volatiles the (Refer Time: 22:39) carbons it will give us SO etcetera. So, these are the reduction part. So, once this pyrolysis is giving up SO to CO etcetera and this air the carbon will be reacting with CO carbon with reacting with CO2 we react with H2O and it will give us to CO; it will give us H2 plus CO.

So, IO 2 that is giving us CO. So, this type of reaction is going on. So, reduction reaction and then further it will go for oxidation this will go for oxidation is at higher temperature oxidations and it will give us ultimately H2O, CO2, NOX and SOX. So, this is will give us the NOX and SOX. So, this is here evaporation and these are heterogeneous phase reactions and this is your homogenous all the vapor heat reactions, but here solid and gas phase reaction. So, that is going on inside the system.

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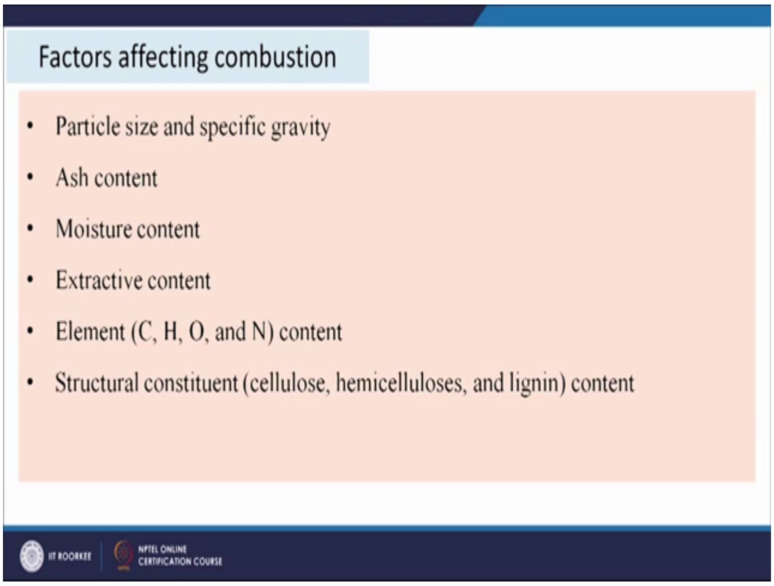

So, the factors which affect the combustions or particle size and specific gravity as we have discussed as content as content also influences the performance of the combustion process moisture content extractive content more extractive more the combustions elemental composition carbon hydrogen nitrogen and oxygen present inside it and structural constituent like say cellulose hemicelluloses lignin it present in waste water waste solid waste the lignin continuing solid waste will be more difficult to combust then cellulose and hemicellulose containing waste.

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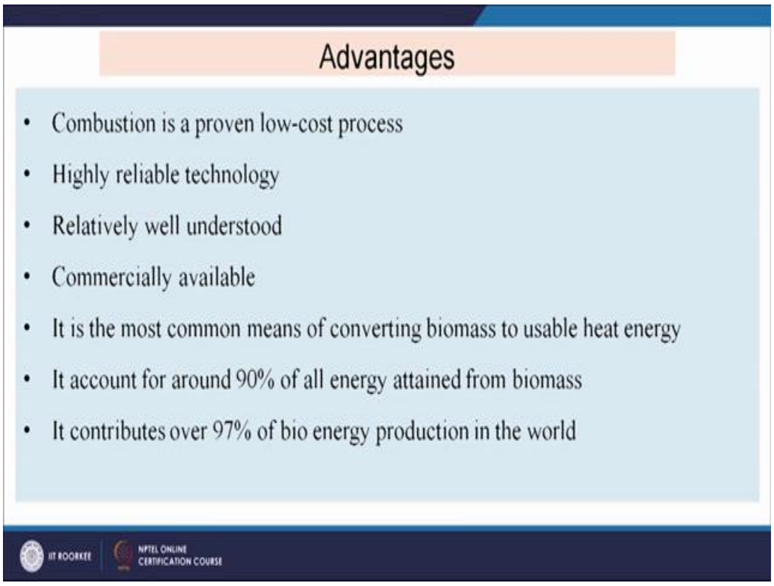

Then this combustion process have some advantages its it is a very proven low cost process highly reliable technology it is relatively well understood and commercially available, it is the most common means of converting biomass or waste usable heat energy and it contributes one ninety seven percent of bio energy production in the world.

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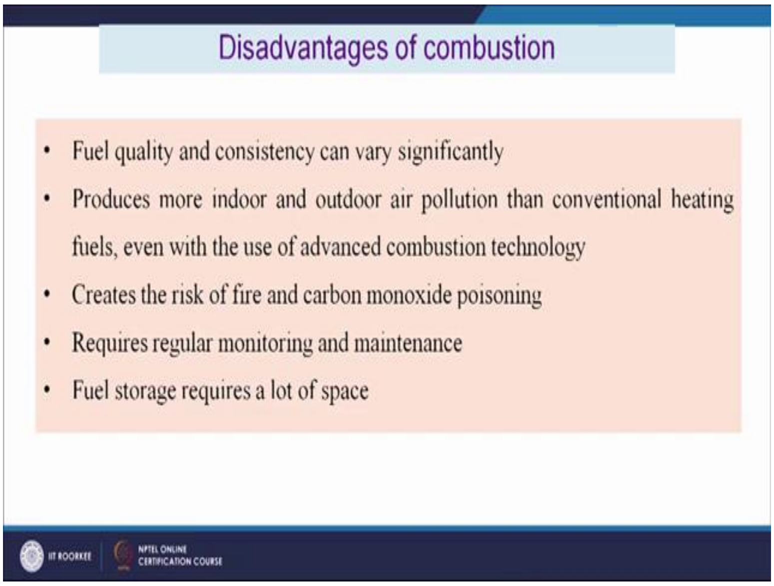

But it has some disadvantages also like say fuel quality and consistency can vary significantly produces more indoor and outdoor air pollution than conventional heating fuels and even with the use of advanced combustion technology creates the risk of fire and carbon monoxide poisoning requires regular monitoring and maintenance and fuel storage requires a lot of space.

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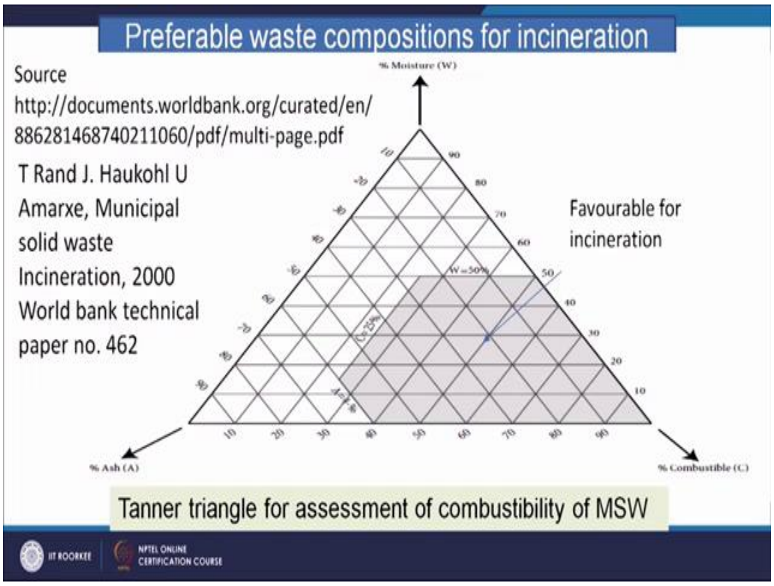

Now, how can you select the solid waste for this incineration purpose? We can do it depending upon 3 properties one is ash content, another is moisture content and another is fixed carbon or carbon content. So, here this portion is basically suitable for incineration and this is tanner triangle, this is used for the assessment of combustibility of (Refer Time: 26:17) solidest. Now let us see the flow sheet how the solid waste is converted to energy through the incineration route.

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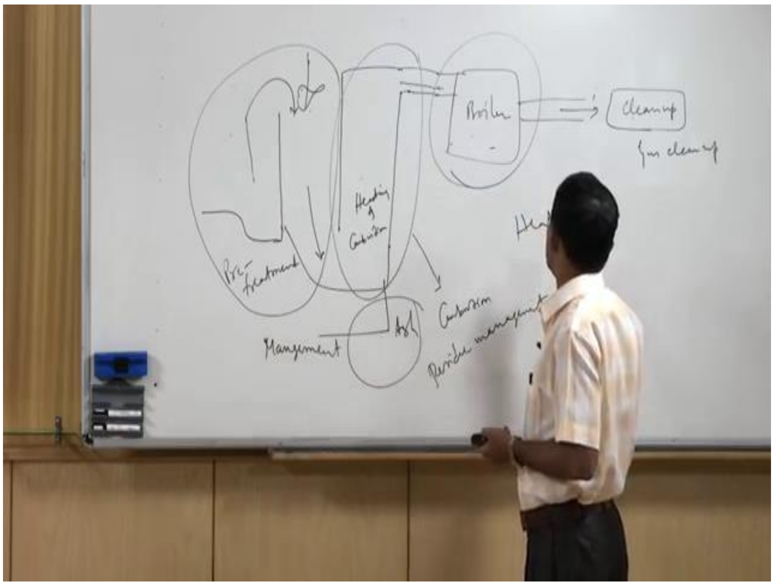

So, in this flow sheet one system is required for the combustor that is there and we need to feed the material inside it we need to feed the material inside it and that is done by some means that is done by some means. So, the solid material which is coming with some cranes or some management it is lifted and put in the incinerator put in the incinerator and homogenization of the solid waste is required.

Then it is coming to incinerated heated here heating and combustion heating and combustion. So, gas is going to that hot gas will go through the boiler part. So, this will go to the boiler part. So, that boiler will use the steam will form the steam and the gas which is being exhausted that will go through clean of and then it will be exhausted and hear from the combustion will get ash that has to be managed through land filling. So, if we think about the whole process flow sheets. So, one is this part that is pre treatment part. So, this part is to pre treatment second part is this one combustion third is heat recovery this is solid waste management means residue management and this is your glass clean of.

So, for the pre treatment we use sorting we can use homogenizing and shredding this will help to make the uniform property the homogenization and to reduce a particle size. So, that that can be suitable for particular type of reactors and the second part the combustion zone when the material is combusted here in incinerator, the heat recovery can take place in different ways one is that this combustor itself content some water tubes that is water wall units and due to evaporation steam is formed.

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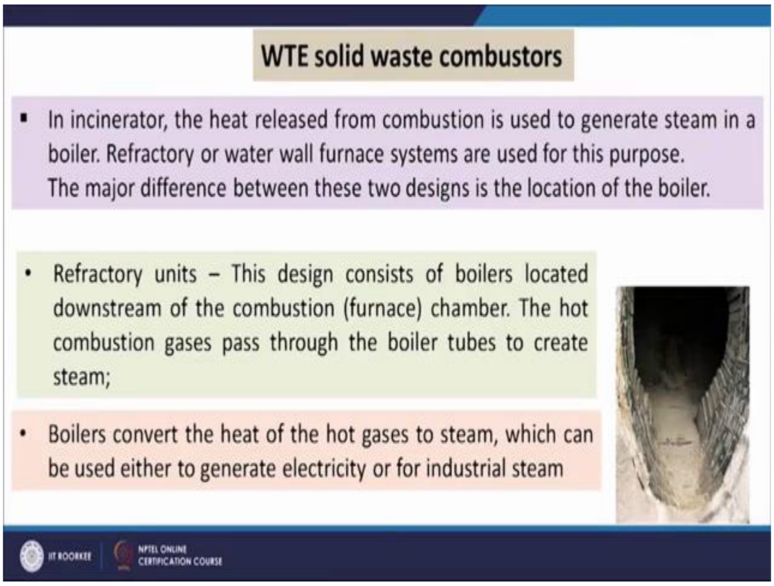

In another case, the boiler is used from this form is that is refractory unit the gas is going out and it enters to the boiler and then in boiler the steam is generated. So, after this in this module we will start discussion in the next module on different types of incinerators gas clean of etcetera.

Thank you very much.