Waste to energy conversion
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Lecture – 11
Gasification-2

Hello friend. Now we will discuss on the second part of the module Gasification. In the first part of this module we have discussed on the fundamentals of gasification processes, the process, and flow sheets advantages etcetera. And we have also made some introductory discussion on different types of gasifiers for coal gasification. In this module we will discuss on the gasifiers for biomass and wastes advanced gasification process, plasma gasification and the comparison between incineration and gasification.

Now we will make some more discussion and comparison among three conventional gasifiers, which are used for coal gasification. Basically, fixed bed fluidized bed and entrained bed gasifiers because the same concept will be applicable for the development of the gasifiers for biomass and wastes.

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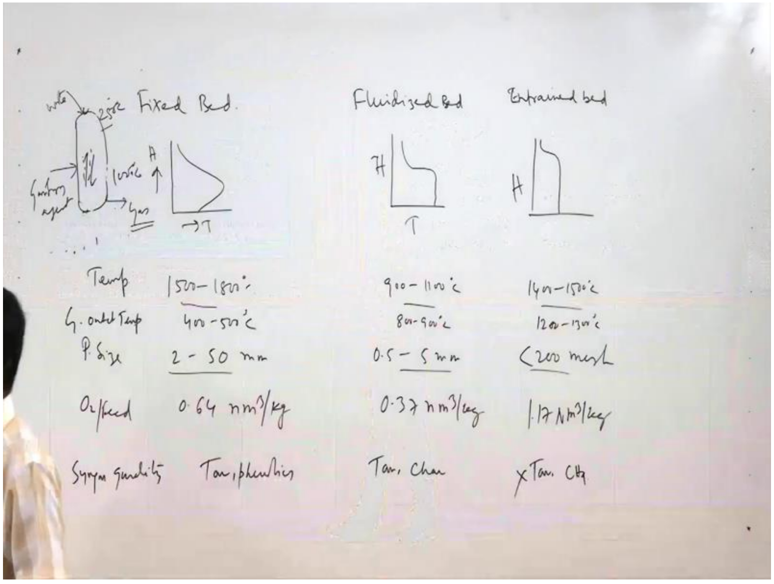

In the previous part, we have seen that for fixed bed gasifier, the temperature is maximum at the combustion zone or coal gasification. And then it decreases this is along height and this is temperature and for fluidized bed. We had seen that the temperature is almost constant and very high, up to certain height of the gasifier, but above that the gasifier the temperature is small less. And for entrained bed we are seen that along the height the temp the temperature is very high. Now we will be considering some more parameters for comparison, the number one say gasifier temperature. So, for fixed bed this temperature is very high say around say 1500 to 1800 degree centigrade for fluidized bed these is less say 900 or say 1100 degree centigrade and entrained bed this is say 14 to 1500 degree centigrade.

We if you think about the size particle size, and then particle size for fixed bed is bigger, say 2 to 50 millimeter here the fluidized bed 0.5 to 5 millimeter, and for entrained bed this is less than 200 micro mesh that is around 70 micro meter. If we think about the oxygen requirement, then that is oxygen by feed ratio in this case this is around 0.64 normal meter cube per kg, and for this is 0.37 normal meter cube per kg, whereas, for entrained bed this is higher 1.17 normal meter cube per kg. Then gas outlet temperature if you think gas outlet temperature, for fixed rate this is lesser say 5 or 600 degree like this. So, 400 to 500 degree centigrade, but here we will get around say 800 to 900 degree centigrade and here we will get more say 1200 to 1300 degree centigrade.

So, these are the basic parameters which we can compare. And we also compare the quality of the syngas. So, quality of the syngas for fixed bed syngas quality, it will be containing good amount of tar; so tar and phenolic. Here fluidized bed also will be having tar and char. Char particles will also be carried away through the gas and will be available in in in to this syngas, but for entrained bed we will not get no, tar no tar and CH4 is also less. So, quality wise this entrained bed is the superior 1. If we replace goal by biomass and waste in this conventional gasifier systems, we will also seeing the similar trend, but there will be some difference as the coal is very less reactive with comparison to biomass and waste.

So, the temperature requirement for biomass and waste gasifier will be lower than these values. These values will be lower. So, the gas outlet temperature will also be lower and as the biomass and waste are lighter than coal. So, the particle size can be handled for biomass and waste gasification will also be more than this size, oxygen requirement will also be different, because in biomass and waste more amount of oxygen is available with comparison to coal, but the similar phenomena similar trend we will see. Now we will discuss on different types of gasifiers for biomass and waste. The first gasifier for biomass and waste gasification is a fixed bed type. And fixed bed gasifier is divided into

2 types that is updraft and downdraft. In updraft gasifier was developed in 1976 by Georgia tech institute of technology. And in this gasifier just like fixed bed gasifier or coal the material or waste or biomass it is put from the top and from the bottom gasifying agent.

This can be oxygen steam. So, the biomass and waste and the gasifying agent is getting less time for contact because there is some counter current flow. And when the material is coming down bigger size particles and the gasifying agent is going up. So, there is a good chance of the blocking of this and channeling. So, there will be chance of channeling and bridging. So, these are the disadvantage of this process and another most important disadvantage of this process is that, the outlet us temperature is 250 degree centigrade whereas, as the inlet temperature inside the combustion zone temperature is around 1000 degree centigrade this is for updraft fixed bed gasifier for biomass and wastes.

So, due to this low temperature and less conduct time the syngas will be continuing high amount of tar. Around 25 percent tar is present in case of updraft biomass gasifiers. And to remove this disadvantage of this of updraft gasifier as shown here the new development of this gasifier was downdraft gasifier. In downdraft gasifier the waste is put from the site and gasifying agent is also put from the middle part. So, here we are giving gasifying agent and we are giving her the waste or biomass. And we are collecting syngas here we are collecting syngas here. So, the material and gasifying agent is flowing parallelly inside the gasifier and getting more chance for contact and reactions. That is why the syngas is getting better quality than that of the updraft gasifier and as the temperature is also higher than 250 degree centigrade.

So, tar content is less here, but the disadvantage of this gasifier type is that the scalar problem this gasifier has some scalar problem the temperature inside this is around say 1000 degree centigrade again it is 1000 degree centigrade. Now we will see for fixed bed gasifier flu fluidized bed gasifier. So, fluidized bed gasifier the temperature is lesser than the fixed bed. So, it is within 500 to 900 degree centigrade. And the particles are also smaller then these fixed rate or almost similar to fixed rate, depending upon the velocity of the gasifying agent we can get basically 2 types of fluidized bed gasifier, one is your bubbling fluidized bed and another is your circulatory circulating fluidized bed.

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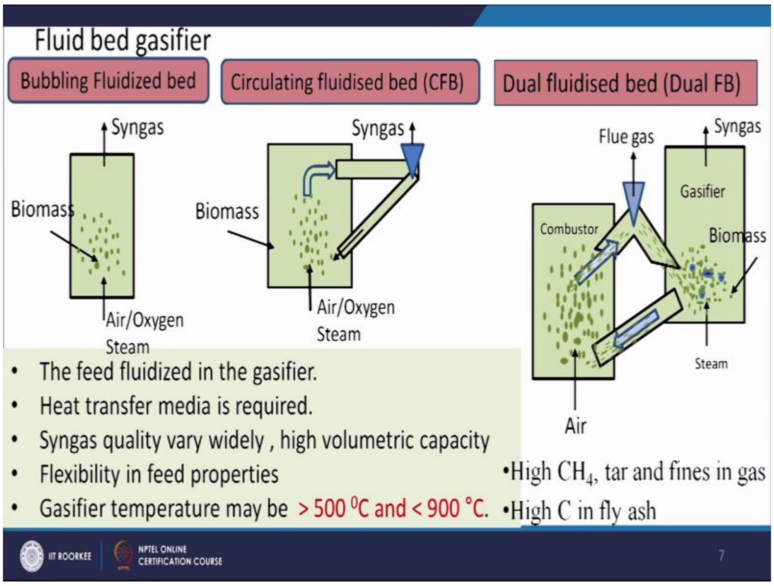

So, this bubbling fluidized bed and circulating fluidized bed the main difference is that the gasifier gasifying agent's velocity is higher in case of circulating fluidized bed and un-converted materials are recycled to the gasifier.

So, here some heating media is required sand media is used for the transfer of heat. This system has some advantage, that it can produce larger amount of syngas and handle larger volume of the gasification media. And it has some disadvantage that the quality of syngas is not that good, it is having some more amount of CH4 for methane and some tar also. And also it has high carbon or char particles in the syngas. The new development for the biomass and waste gasification through fluidization, is that dual fluidized bed gasifier in dual fluidized bed gasifier 2 chambers are used the first is combustor and the second is gasifier. So, in the combustor we send controlled amount of oxygen and in the gasifier we send steam.

So, the regasification reaction is going on. Now we will go to discussion the entrained bed gasifier. So, entrained bed gasifier in this case biomass or waste and gasifying agent oxygen or steam all are put inside the gasifier from the top. And the solids and the gasifying agents flow parallely gets more time for contact and temperature inside is also very high. So, this is around say 1200 to 1400 degree centigrade. So, that high temperature, high conducts time and particle size is also less. So, all these factors help to get more conversion and to produce good quality syngas this syngas contains less CH4 nodes no carbon no char and no tar.

This is of superior quality of syngas and this syngas is mostly suitable for chemical production. And this is also suitable for very large scale production. These are 3 conventional gasifiers which are developed on the concept of coal gasification later on a new type of gasifiers has been developed for the gasification of biomass and waste. Particularly those portions of the solid waste those are hazardous in nature. So, this new type of gasifiers which is developed that is called as plasma gasifier. So, in case of plasma gasifier unlike other conventional gasifiers, we do not need to send gasifying agents like oxygen or steam in spite of that we need to get some high voltage across 2 electrodes.

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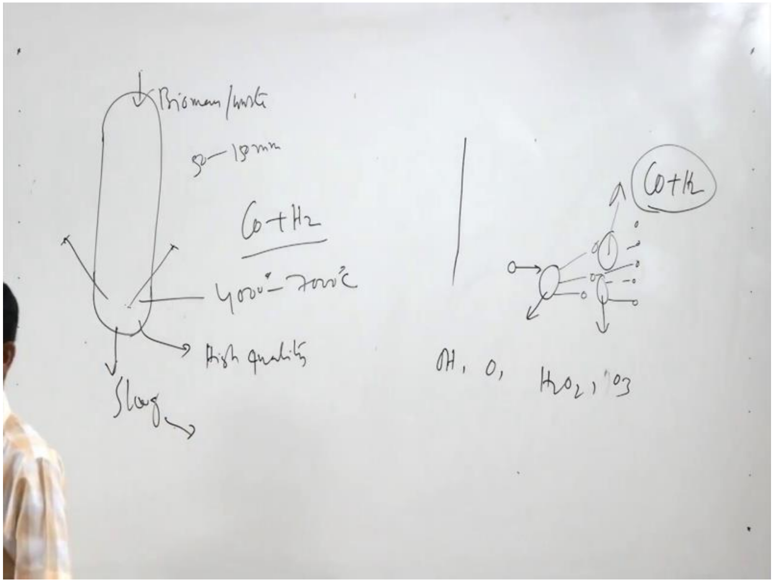

So, high voltage given across these 2 electrodes produces plasma torch, and that creates very high temperature here that is say 4000 degree centigrade to 7000 degree centigrade. So, this high temperature generated here helps the conversions of the solid waste present in it and biomass present in it to gaseous products and when carbonaceous feed stocks comes inside these. So, CO and H 2 rich gas is obtained are under certain condition. The advantage of this gasification system is that no oxygen steam is required any type of solid waste can be used here, no pretreatment is required and the quality of the syngas the quality of the syngas is very high; high quality syngas why high quality the high temperature that helps to neutralize the acid gases. This high temperature helps to convert all the metals in as to it is metallic form.

So, the slag which is formed here that is in pure forms, pure metal form. Or this material is having very less leaching property. So, nothing is leachable here. So, the management of this is easy and that can be directly used also. So, that is the advantage of the system, but this is not. So, well matured or extensive research is going on for the commercialization of this plant or this reactor. Now we will see the mechanism of the plasma gasification how the mechanism differs from that of conventional gasifiers. In conventional gasifiers we have seen that the for the gasification, some other fuels is burnt at the initial stage then the biomass or waste or any carbonaceous material is partially combusted to produce it. In this case that initial firing is different. We need to provide high temperature by the application of high voltage across 2 electrodes. And these 2 electrodes when it is under high voltage with accelerate the velocity of electron generated here.

So, free electrons velocity will be accelerated. So, this fill electron will then try to collide with nearby molecules, disintegrate it and to generate further electrons. So, when it is colliding other molecules. So, it will help to create further electron when these will collide other molecules again this will give further electron. So, number of electrons will gradually increase. So, number of electrons will gradually increase and that will proceed. And that will create one avalanche or streamer of this electron. And then this streamer when more voltage will be applied will generate high temperature as well as it will produce different radicals from these materials, from these materials they will produce different radicals like say O H O H 2 O 2 O 3 is also O 3 can also be produced depending upon the security of the conditions. And under certain conditions if carbonaceous material is put here, in plasma gasifiers then the predominating product in gaseous stage is CO and H 2.

So, this is the fundamental mechanism for the production of syngas in plasma gasifier. Now we will see how can you select a suitable gasifier type for a particular biomass and waste feed stock. On the basis of this discussions it is very clear to that the different conventional gasifiers can handle different particle size of the biomass and waste. So, in this case fixed bed the typical particle size is 50 to 150 millimeter. So, this is bigger than the corresponding value for coal gasification in fixed bed. For fluidized bed again it is 50 to 150 millimeter, but in case of entrained bed we are getting less than 1 millimeter and for circulatory fluidized bed this is less than 20 millimeters.

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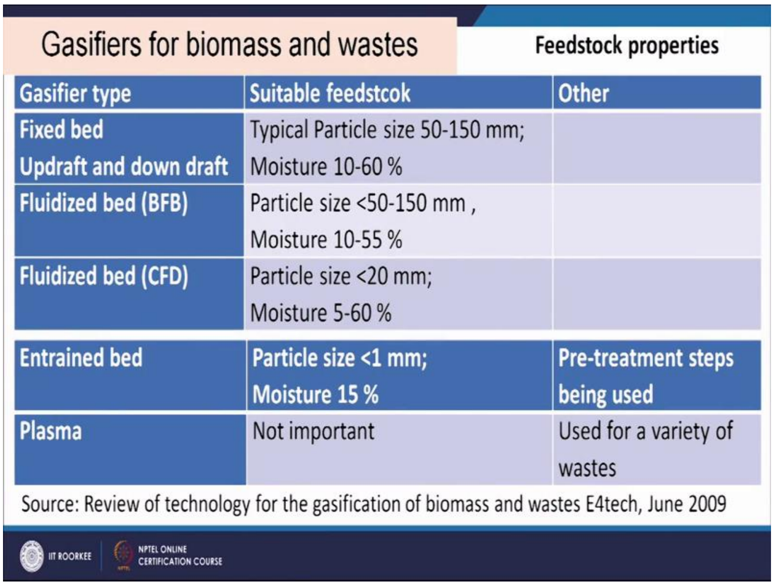
Gasifiers for biomass and wastes

Feedstock properties

Gasifier type	Suitable feedstcok	Other
Fixed bed Updraft and down draft	Typical Particle size 50-150 mm; Moisture 10-60 %	
Fluidized bed (BFB)	Particle size <50-150 mm , Moisture 10-55 %	
Fluidized bed (CFD)	Particle size <20 mm; Moisture 5-60 %	
Entrained bed	Particle size <1 mm; Moisture 15 %	Pre-treatment steps being used
Plasma	Not important	Used for a variety of wastes

Source: Review of technology for the gasification of biomass and wastes E4tech, June 2009

So, the particle size here is relatively bigger than that of the coal gasifiers, but for plasma gasifiers there is no limitation any particle size can be used and here is a one important thing that moisture content the moisture content in biomass is very high with respect to coal, but this fixed rate fluidized bed and this reactors or gasifiers can handle biomass with high amount of moisture, but for entrained bed the moisture content is less, but plasma gasifier any moisture can be used. Now we will see some technology licenses.

Actually, the first the coal gasification or coal gasifiers were developed and licensed by many technology licensors. Later on the concept of biomass and waste gasification came and some other companies worked on it and they had licensed their technologies.

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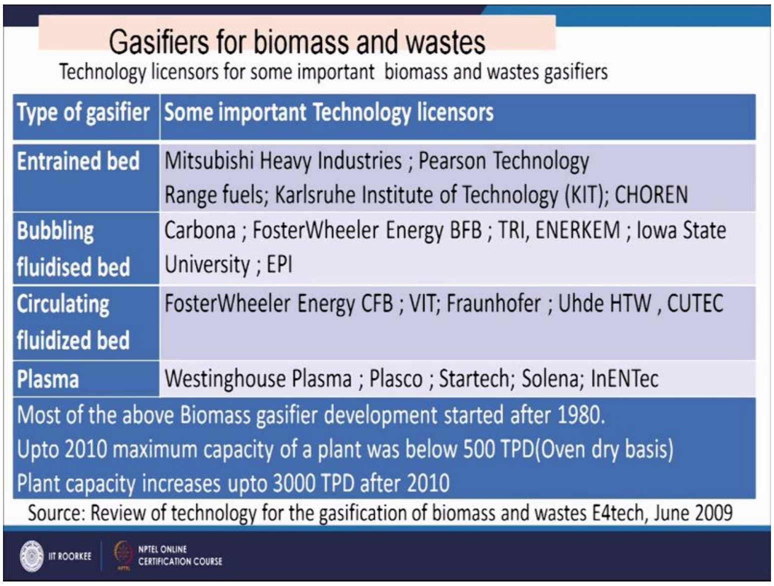

Gasifiers for biomass and wastes

Technology licensors for some important biomass and wastes gasifiers

Type of gasifier	Some important Technology licensors
Entrained bed	Mitsubishi Heavy Industries ; Pearson Technology Range fuels; Karlsruhe Institute of Technology (KIT); CHOREN
Bubbling fluidised bed	Carbona ; FosterWheeler Energy BFB ; TRI, ENERKEM ; Iowa State University ; EPI
Circulating fluidized bed	FosterWheeler Energy CFB ; VIT; Fraunhofer ; Uhde HTW , CUTEC
Plasma	Westinghouse Plasma ; Plasco ; Startech; Solena; InENTec

Most of the above Biomass gasifier development started after 1980.
Upto 2010 maximum capacity of a plant was below 500 TPD(Oven dry basis)
Plant capacity increases upto 3000 TPD after 2010

Source: Review of technology for the gasification of biomass and wastes E4tech, June 2009

So, here some tech important technology licensors are tabulated for entrained, bed bubbling fluidized, bed circulating fluidized, bed and plasma gasifiers. From this table we see that as mentioned here most of these above biogas or waste gasifiers are developed after 1980 and up to 2010 the capacity of these gasifiers was less that is around 500 ton per day, but after 2010 the capacity of these type of gasifiers H as increased and now up to 3000 ton per day capacity is available. Now we will see the flow sheets of plasma gasifier as the mechanism is changing for plasma gasification; obviously, the flow sheet will also be changing and we will have some discussion on the change in flow sheet in the plasma gasifiers or in plasma gasification process.

So, main change will be with the pretreatment in case of entrained bed gasifier pretreatment is essential, but in case of plasma gasifier no pretreatment is required.

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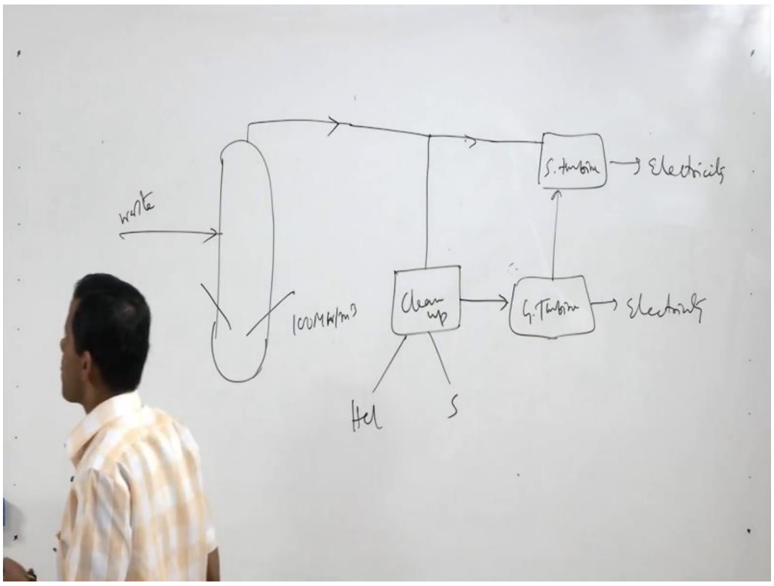

So, the waste can be directly charged to the gasifier without any pretreatment can be charged. Another is we do not need to supply oxygen air in spite of that we will give external source very high voltage. So, voltage that it can generate 100 mega watt per meter cube power density than the syngas switch will be generated here the quality will also be different with respect to the syngas generated in conventional gasifier. In this case the acid gases will be neutralized and will be converted to molecules like say HCL not chloride the HCL will be available in this. So, Sulphur will be present in elemental Sulphur.

So, when does syngas cleaning and conditioning concept will come? So, during the cleanings time we will get through syngas cleaner. We will get HCL we will get Sulphur unlike other gasifiers we get acid gases H 2 S etcetera and we again convert this is t OH 2 elemental Sulphur, but here directly this conversion takes place this is major difference in the flow sheet and then when it is coming the syngas it can go and it can be used for the steam production and then steam turbine. So, steam turbine. So, electricity, and this gas after this cleanup we will get clean gas and that clean gas can be used in turbine because the high temperature is there. So, that can be used in gas turbine, and that gas turbine the gas exhaust of the gas turbine will go for further combustions or for steam productions and then electricity we can get.

So, this is the flow sheet of the plasma gasification process. And we have seen some differences between this flow sheet and the conventional gasification flow sheet which we have discussed in the first part of this module. Here we will see some biomass and waste gasification plant around the world.

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Some biomass and waste gasification plants

Country	Plant Name	Feedstock	Products	Syngas cleaning option	Year
Australia	Whytessgully waste to energy plant	Biomass	Electricity	-	1999
Brazil	Brazilian BIGCC plant	Biomass	Electricity		2003
Canada	MSW plant	Biomass	Electricity		2000
Canada	Toronto MSW plant	Municipal waste	Electricity		2000
Germany	Schwarze pump gasification plant	Municipal waste	Electricity and methanol	Rectisol	1992
Germany	Fendoteoc gasification plant	MSW	Electricity		1999
Sweden	CHRISGAS project	Biomass	H_2, automotive fuels		2008/09

As evident in this table around the world the biomass and waste gasification plants are available and these plants are available since 1990s. Here some lists are given in Australia, Brazil, Canada, Germany, and Sweden. So, all those plants are basically based on biomass or municipal waste and most of these are producing electricity. They are not going for any other chemical synthesis except one or 2. Why so? The reason is that the price of the product and the competitiveness in the market.

So, to make the process competitive the process should be of very high capacity. The production capacity should be very high, but biomass and waste gasification process produces less amount of syngas. So, less amount of syngas cannot be processed economically in with comparison to other processes. That is why we are not getting any other applications like except one or 2, but recently that the development is going on. How to improve the economy of the process by using compact reactors? And in that case this process we will also be more suitable the biomass and waste gasification will be more suitable. At last of this module we will compare the incineration and gasification process.

So, for the comparison, we will identify some parameters and we will compare these to thermo chemical conversion methods.

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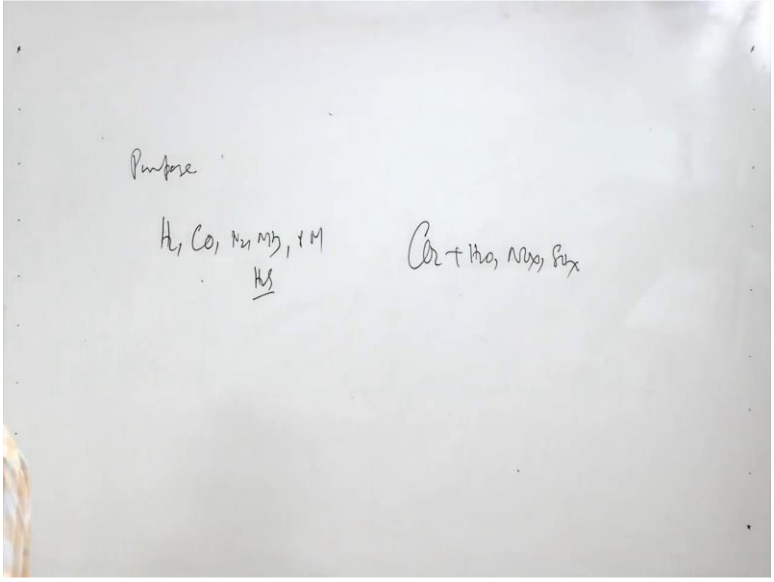

So, purpose, one is purpose. Another is process types. Raw gas and it is utility slack and it is utility and your pressure. So, these are the parameters in if we compare these parameters we see here, the purpose is different gasification is to produce intermediate heating value continuing gas.

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Comparison of gasification and combustion

Features	Gasification	Combustion
Purpose	Generation of valuable gaseous products	Generation of heat or destruction of waste
Process Type	Thermal and chemical conversion using limited oxygen	Complete combustion using excess oxygen (air)
Raw Gas & utilization	H_2, CO, H_2S, NH_3, PM Heat, electricity, chemicals	CO_2, H_2O, SO_2, NOx, PM Heat, electricity
Solid Products & handling	Char or slag Char: fuel Slag: Construction materials	Bottom and fly ashes Land filling Or sold as a material for making concrete
Pressure	Atmospheric to high	Atmospheric

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The gas which will be having intermediate heating value and combustion is to produce flue gas and to extract heat from the waste material and both are thermal process, but gasification takes place with controlled amount of oxygen whereas, the combustion is excess amount of oxygen. We have discussed the R value in the previous module and raw gas the gasification contains H 2 CO and no NOX it contains nitrogen or NH 3 if they are used or p m.

But in case of combustion will be having major CO 2 plus H 2 O we will get NOx we will get sox if Sulphur is present and if Sulphur is present in this case, we will get H 2 S. And solids will be getting char or slag. So, char in case of gasifier can be used as fuel solid fuel. And slag can be used as construction material whereas, for combustion we will get fly ash and bottom ash. So, bottom ash we have to go for line cleaning or it can be used for concrete also. And this gasification requires higher pressure than atmospheric, but combustions works well and are atmospheric pressure. So, these are the basic difference between these incineration and gasification.

So, all these processes have their own advantages and limitations, but both of these processes are important thermal processes for the conversion of waste to energy. So, up to this in module and we will discuss in the next module on syngas utilization.

Thank you very much.