Municipal Solid Waste Management
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Lecture No - 20
Incineration Combustion

Hello students, so we are at model, chemical transformation. It is the 5th functional element. So, in the previous class I talked about whether waste could be useful as a fuel so you got the idea about whether the waste is possible to be used as a fuel again depend upon the different parameter and specially and carefully calorific value. So today we will talk about incineration of proper combustion process.

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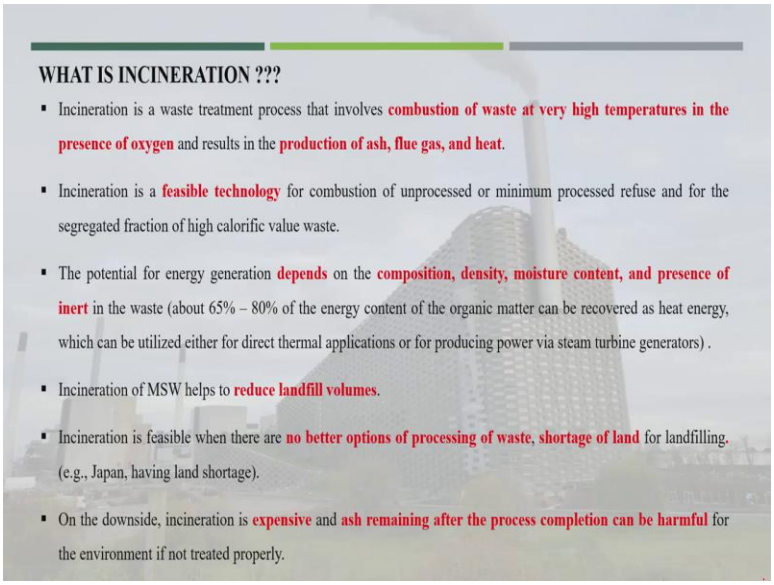

So what is the meaning of incineration? Like incineration is a waste treatment process that involves combustion of the waste at very high temperature in the presence of oxygen. ok, that is the incineration process. We can call it as combustion also in similar way and the result is the production of ash that solid residue will produce after the combustion of the incineration process. As it is a combustion process the gases that will be produced are highly polluted, this is because it is combustion process.

Heat also will get produced from the incineration of combustion process. Here incineration is a feasible technology for combustion of segregated waste, I already told in the previous class also.

If you have a segregated waste specially onto the sources that dry percentage of waste is very good for the incineration process specially the paper plastic is a highly combustible matter and will be at very high calorific value that is possible to be used for the incineration process.

And this is the one of the very best technology to reduce the volume. This solid what I was talking about has a very low percentage, 5% maximum 10% not more than that will be get produced. So means volume reduction is 92 to 95% volume reduction is possible from this technology. the potential of for the energy generation because the energy also that heat we can convert into power or energy production out of that is depend upon the composition, density moisture content and different parameters you saw that especially on to the volatile solids.

If more organic content or volatile solids are more, the energy production will be very high. About 65 to 80% of the energy content organic matter can be recorded as heat energy from the incineration process. Which can directly be used in thermal application for producing power during steam turbine generation, so I will talk about that will get three different products heat will be the first product from that stream which can be produced and from that power we can produce.

As I was talking about incineration is helpful to reduce the landfill volume. Obviously the volume reduction is more. In this case whatever the waste is reaching to the disposal site or a landfill site. There are also likely that landfill site can work for more time. Incineration is feasible when there are no better options for processing, wastes shortage of land for land filling. So this is very important point. There is no better option is available.

So what could be the better option for these dry wastes which has combustible waste also. The better option is recycling which we talked about in the last few modules. Recycling is the better process because they do not need to worry about the flue gas or whatever acid is producing and we do not have much energy. There is no need of temperature as this is very high temperature combustion process. In the recycling process that is the better process or not recycling but reuse also could be possible of that matter. That is a better option.

If those kind of options are not available then incineration is one of the very important technology or better option and also there is a shortage of land, like there is a one example is given like Japan is very small country. The land availability is very low. Very small land available so such kind of country is cannot depend upon to find the land filling of such kind of waste so this technology is better option for such kind of country.

On the downside incineration is expensive process and ash remaining after the process completion can be harmful, not only the ash but also the flue gases produced we need lot of treatment processes to treat the ash also and what flue gas is getting produced during the incineration process.

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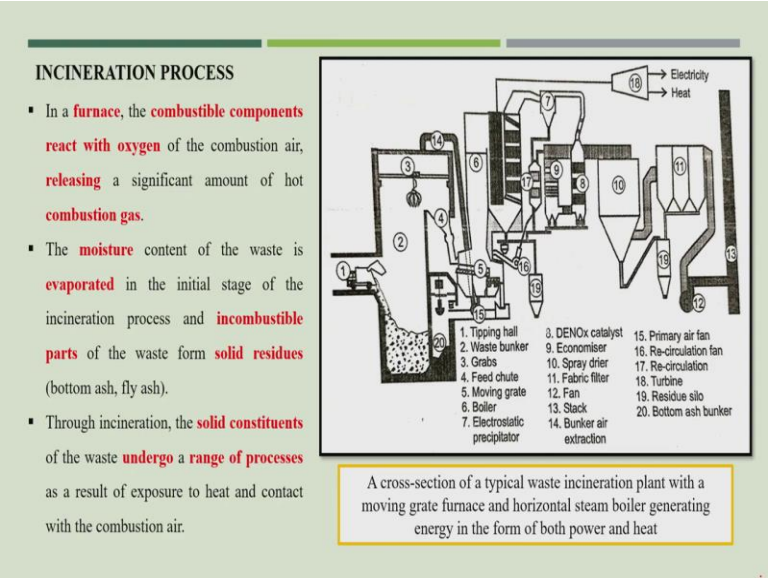

Now the incineration process, what exactly is the incineration process in brief in the Furnace the combustible components react with oxygen on the combustion air release a significant amount of hot combustion gas that combustion gas normally called as in flue gas. The moisture content of the waste is operated in the initial stage of the incineration process and then the combustible matter will get combusted. So, the Furnace is designed in such a way that initially when the waste is received in the incineration process first moisture will get removed and finally the combustion process will get started.

and because of that ash will get produced and it can be possible that un-combustible matter will also come out into the solid waste residue. Through incineration the solid constitutes of the waste undergo a range of process the result of exposure to heat and contact with the combustion air. So, whatever the solid that dry matters we are putting into the incineration process or in the furnace that will undergo range of combustion processes.

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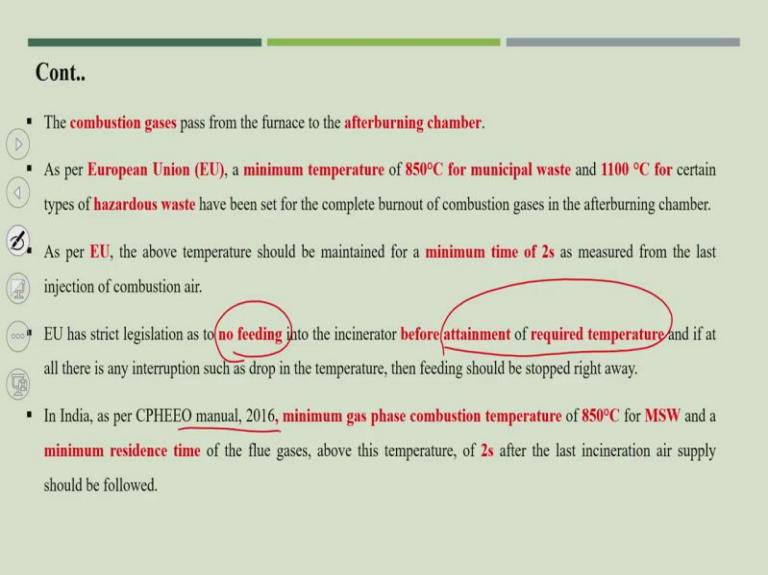

Then the combustion gas passes from the furnace to the after burning chamber again, it will get after burning process and from that we can produce heat and because of that heat we can convert into the steam and the steam we can produce power from that particular combustion gas. In the European Union, minimum temperature of 850°C for the municipal waste and 1100°C for certain type of hazardous waste that is for the complete burnout for the combustion gases in the after burning chamber.

So you see that the European Union was the first, I can say is the first union of countries that finalized the temperature at 850°C in the first chamber and after burning process of this combustion gas the temperature is final at 1100°C and this temperature should be maintained for minimum time of two seconds as measured from the last injection of combustion air.

So that first time the European Union came up with such kind of standardization of the Furnace temperature. And now I think lot of country like India also have come up with some kind of

legislation, which I am going to show here. See here you have strict legislation as, feeding into the incineration before attainment of required temperature. No feeding is allowed before attainment of required temperature, this is a part of strict legislation.

If you are not getting temperature at 850°C, we cannot feed that kind of waste in the Furnace process and now because we have also the solid waste manual 2016 also now India also come up with this kind of centralization. The minimum gas phase combustion temperature same 850 °C for MSW and minimum residence time of the flue gas is above the temperature in 2 seconds after the last incineration air supply should be followed this standardization also come up. I will give few more standardization or suggestion by the solid waste manual of 2016 if you try to install some kind of incineration plants in India for specially for the MSW.

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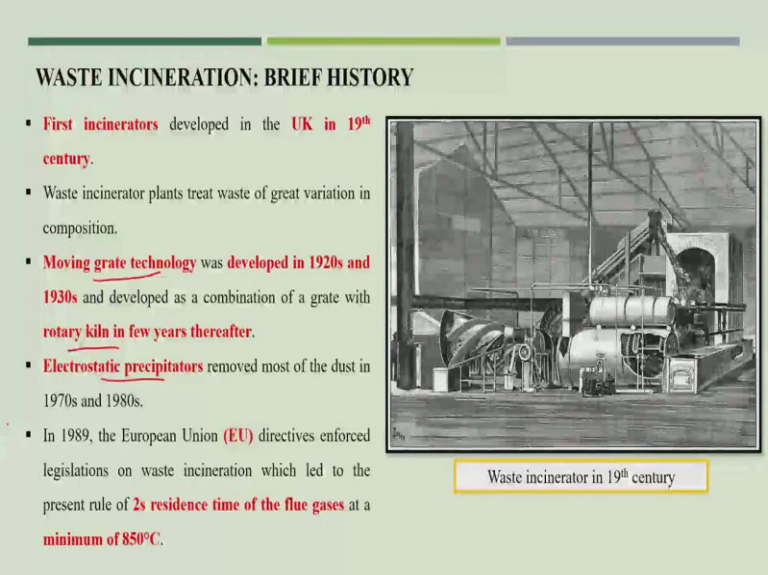

Now before going to the incineration process, I thought of showing you, some brief history about the incineration process. So the first incineration developed in UK during 19th century is very old method here problem was the; specially all European countries and specially UK the land availability was very low and because they started in distillation 100 years before. So, this industry did not have proper treatment process for their solid residue or not for polluted water also wastewater and not for the solids also.

And most of the waste I think are combustible so that was the idea behind the starting the incineration in the 19th century in the European countries. Waste incineration plant treat waste of grate variation in the compositions obviously in those days 100 years or 50 years before in the European countries also the compositions was very large variation use to we get it, and this is one of the technology of incineration process.

We are also going to talk about moving grate technology was developed in 1920 and 30's and develop in a combination of grate with Rotary kiln. This is another technology normally we can find this rotary kiln after the moving grate Technology so both the Technologies together which I am also going to talk in the next lecture. So this is this is very old technology. See idea of sharing this brief history because we have lot of literature available that is the idea.

If more literature is available, it means we have a lot of data available with us. So data means I think wherever I think if you are planning to how the incineration facilities, I think those kind of data is on literature is available to easy to get install the incineration facilities in any country, and this is one of the true gas treatment Technology electrostatic precipitator. So this also will going to talk into the next lecture when you talk about the cleaning of a treatment of flue gases.

I think it was started in 1920 and 30 this technology has come up in 1970 and 30 so until that there was no proper treatment. This is one of the very important technology to treat the solid concentration in the flue gas or specially we can say dust this very small particles of the dust also can be removed from the flue gas, and the flue gas is very highly temperature gas temperature goes up to 800, 600°C temperature from that dust is getting removed by this kind of Technology.

In 1989 the European Union came up with this kind of directive which I think in the last slide. I showed it at 50°C with 2 second residence time in 1989.

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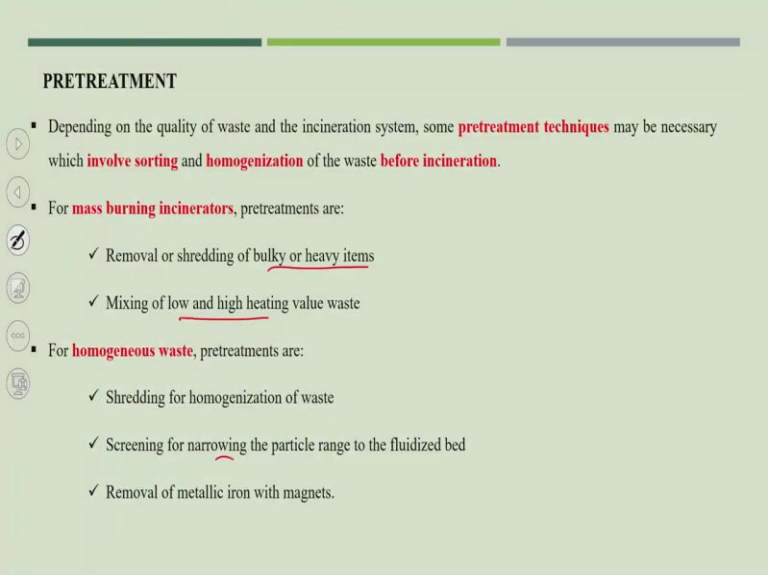

Now we will talk about the combustion technology so commotion system is commonly referred as a heat of an incineration plant that is a combustion system. The combustion system can be classified in two different types. First is mass burning of the non-homogeneous waste, it is a simple combustion mass burning complete burning and specially for non-homogeneous waste. and we are also especially in the developing country like India we are getting a lot of non-homogeneous kind of waste means a lot of nitrogen is intragenic city in the waste for such kind of technology combustion system could be possible to use by our country also.

So this is moving grate technology and other is a burning of homogeneous waste of limited particle size. So this is another technology which, we are going to talk about fluidized bed incineration plant. This is especially for the homogeneous waste and limited particle size particular size is required normally there such kind of technology is not that beneficial for the MSW but I think we need to know that if suppose you are planning for very special kind of waste like sewage sludge like even plastic itself alone such kind of Technology could be possible to use.

Now I think before incineration specially the India we required free treatment of waste treatment of that dry components of the waste. So depending on the quality of waste the incineration system pretreatment technology may be necessary which involve sorting and homogenization of the waste before incineration that was the idea behind the pretreatment that sorting means

contaminants between contaminants or non combustible, non combustible metals will we get removed or sort out from the that particular material.

and try to make homogenize the material at least not homogenize in the type of waste composition of waste, at least the size could be same so that combustion will be some more beneficial. So mass burning incineration technology the pretreatments are removal of shedding of bulky or heavy items. The large size item also is difficult to get burnt out completely burnt out into the furnace. So, bulky items or heavy items will be get be moved out and mixing of low and high heating value.

So this is also a very important idea of pretreatment because if you see that the waste is collected from different locations from the city under the different vehicles are coming to the incineration facility. So it is possible that sometimes the vehicle coming with the lower calorific value of waste. And sometimes is possible the very high calorific value of waste is coming to the inception facility so I think this is also one of the very good ideas if you can mix to both kind of waste.

So, we will get proper temperature into the furnace that is what the standards to maintain the temperature of 850°C for homogeneous waste treatments are. So this is for the second combustion system facility the pretreatment is required for shredding of homogeneous waste. Screening and narrowing of the particle range to the fluidized bed, narrowing means small size, small size making for the fluidized bed technology and removal of metallic iron with magnet because specially not only metal but glass also has to be removed out from this technology.

Suppose from the mass burning incineration the metal item or glass items is not getting sorted out those are not combustible items that will come out into the solid residue but that would not create any problem in into the Furnace.

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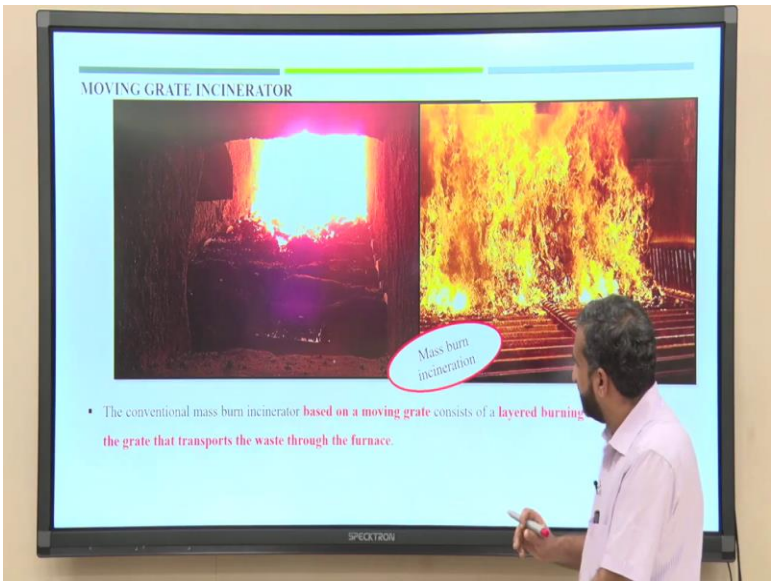

So now we will go for types of incineration ok there are three different types of incineration. So, first is the moving grate incinerator. So this is a very simple incineration facility which is very well known technology. I think same similar kind of technology we can get in the coal power plants also similar. So here in the inside furnace will find the grate I will show you some of the photograph and some pictures of the grate, which you can understand.

The conventional mass burn incineration based on the moving grate consists of a layered burning of the waste on the grate that transports the waste through a furnace. See it is a layered burning of the waste on the grate the combustion will be on the grate. And this grate will transport the waste through the furnace for the entire furnace.

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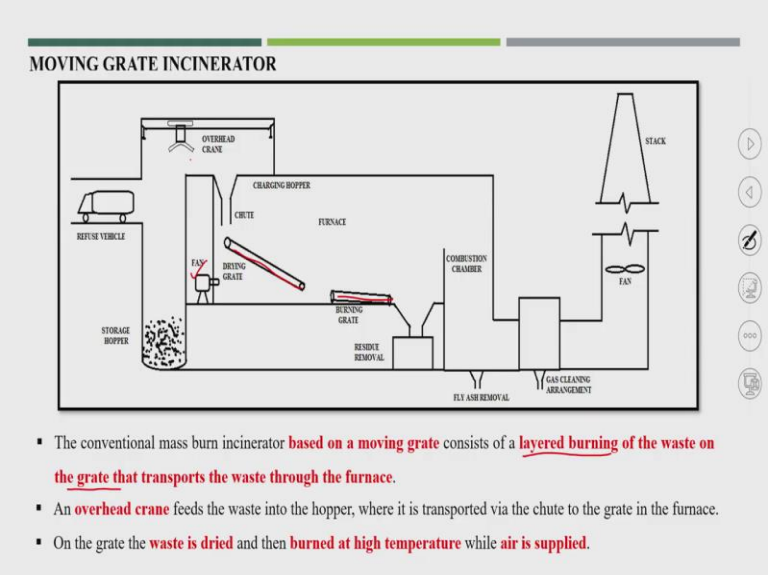

Now this is the line diagram. You can see that solid refuse is coming to the storage hopper. This is the overhead crane through the crane the waste is feeding into the incineration for this facility. So this is a furnace and these are the grate, this is one great. This is the other grate. So this is for drawing one and fan is provided in the bottom of the grate so that the air is supplied to the furnace. So here waste is getting combusted and finally this solid residue will come up.

This is the second combustion chamber; whatever combustion gas is getting produced that is getting converted in the combustion chamber. After the second combustion chamber the gas will go through the glass cleaning arrangements so here to gas treatment facilities and finally is goes to the atmosphere through the stack. So here it is written the overhead crane feed the waste into the hopper where it is transported by the chute to the grate into the furnace, on the grate the waste is dried and this and then burnt at high temperature while air is supplied.

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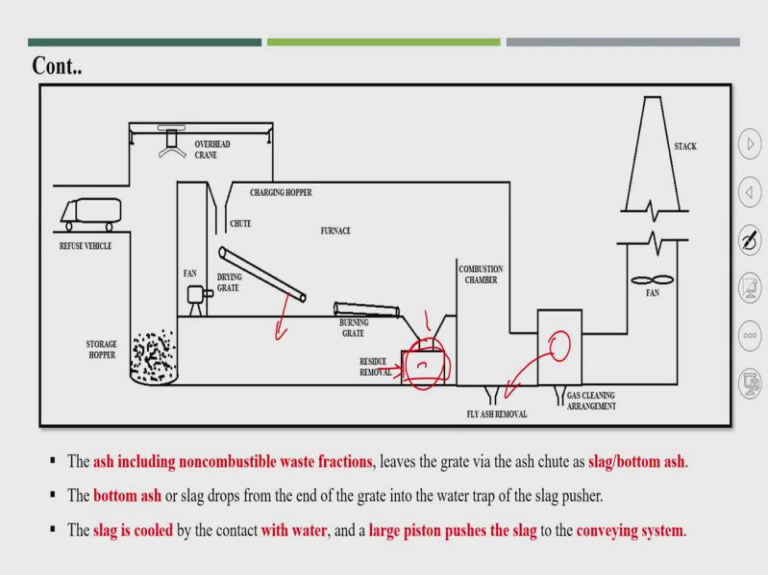

Now the ash including non-combustible waste fraction leaves the grate why they are issued as lag of bottom ash so this is what the bottom ash. This is another ash very small particle size of the as you also produced through the grate. Once you will talk about the solid residue. I will explain properly and here also even the flue gas cleaning treatment facility lot of fly ash will get produce into these treatment facilities.

And the bottom ash slide drop from the end of the grate into the water trap of the slag pusher. So this is a slag pusher here this is a simple water tank. So whatever the bottom ash or the ash is produced that is going into the water ok, because a very fine particle. So for storage and from that there will be a slack pusher up this tank will get removed out once it is get filled up completely then another tank is getting provided into the same facility or same material.

So the slag is cooled by contact with water and large piston pushes the slag to the conveying system. The amount of slag is the bottom ash of slag. Usually it is 10% to 25% by weight of the waste feed depending on to the waste composition 10 to 25% slag will get reduced by weight.

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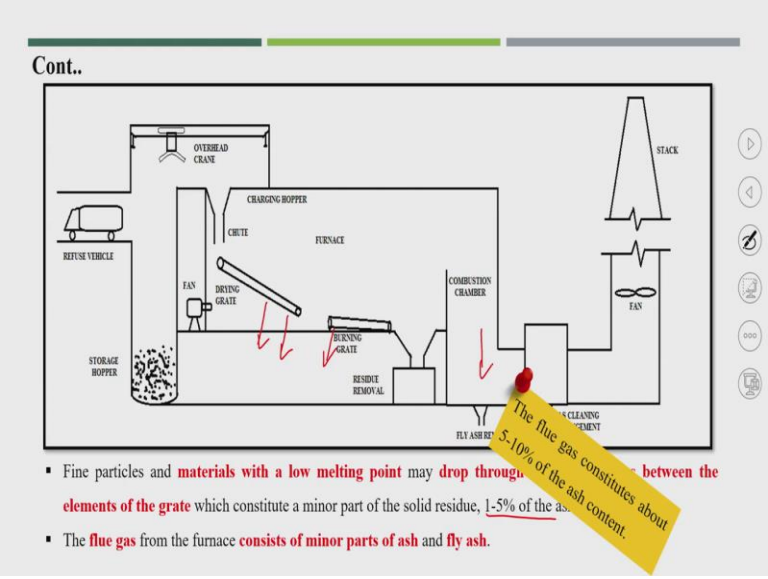

Then the fine particle materials with low melting point may drop through the narrow gaps between the elements of the grate what I was talking about from these also the very fine material fine particles are fine ash is getting produced and that is also producing 1 to 5% of the total amount of ash production. The flue gas from the furnace consists of minor part of the ash from this flue gas also the fly ash will get generated. The flue gas constitutes about 5 to 10% of the total ash content.

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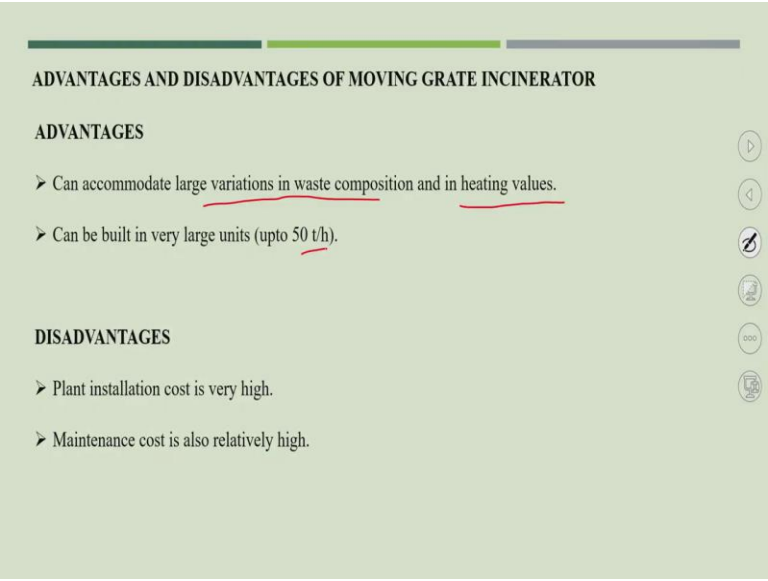

Now what are the advantage and disadvantage of moving grate system? Advantage is that it can accommodate large variation in the waste composition and in heating value. So what I was saying about this technology is highly beneficial for the Large variation of the waste composition

also variation in the heating value and different calorific value mixes could be possible to get combusted into this technology.

It can be built in large unit that is up to 50 tons per hour capacity. So that is what I think/ this technology is very well known in coal power plants. But the advantage here a lot of literature is available there is also another advantage and number of countries has installed this kind of technology. So when any new countries like India is trying to have such kind of incineration facility, we can get a lot of literature specially you can look on to the failure of such kind of incineration facilities.

The disadvantages of plant installation cost are very high and maintenance cost is also relative to the major problem of this technology. This all the incineration facility and combustion facility requires a lot of money. Not only for the capital cost, but also maintenance cost is very high. So because of that only if you are planning for incineration facility and will not be planning for getting any power production or any kind of product from the such kind of facility.

So it will be a very costly process. So, in most of the cases on most of the country when they tried incineration facility, not only for the volume reduction, but also to get some kind of product out of that, so from this product this product could be heat this product could be a steam this product could be a power. From that at least we can get some kind of maintenance cost we can get it out by selling of such products.

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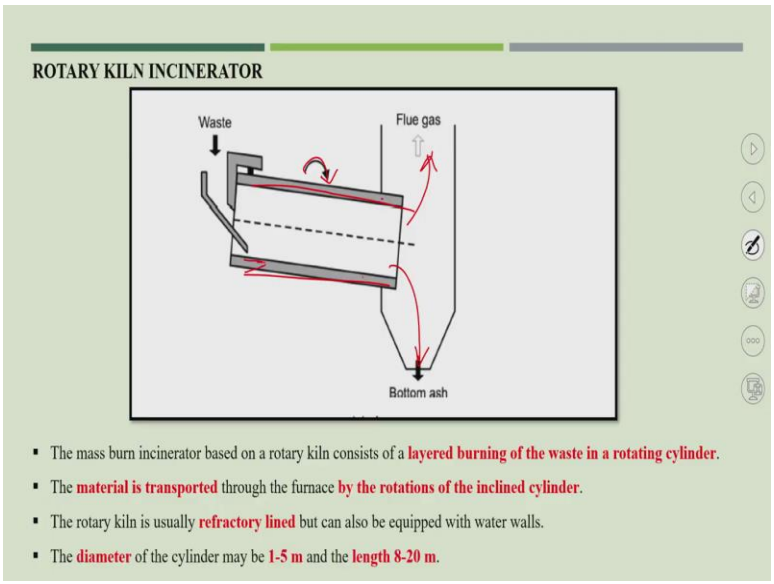

Now next technology is the Rotary kiln incineration. So you see here. This is a Rotary kiln. And after incineration bottom ash is getting produced and the flue gas is coming out. The mass burning incineration based on the Rotary kiln consists of a layered burning of waste in rotating cylinder The material is transported through a furnace by the rotation of the incline cylinder. This is the cylinder. Is getting rotated?

The Rotary kiln usually refractory lined but can also be equipped with a water walls. So these are the refractory are water balls. The diameter of the cylinder maybe 1 to 5 m and the length could be 8 to 20 meter.

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So, this is one of the Rotary kiln you can see here this is the rotary kiln. The capacity would be within the range of 2.4 tons per day to 480 tons per day or 0.1 tons per hour to 20 tons per hour waste production the kiln rotates with a speed of typically 3 to 5 rotations for the; rotation is not that fast. The excess air ratio is well above that of moving grate incineration and the fluidized bed. The fluidized bed the incineration is a third type of incineration type.

So the excess air ratio is required means more amount of air will be supplied for the combustion process. So this is another incineration facility. This is from the China rotary kiln combustion facility.

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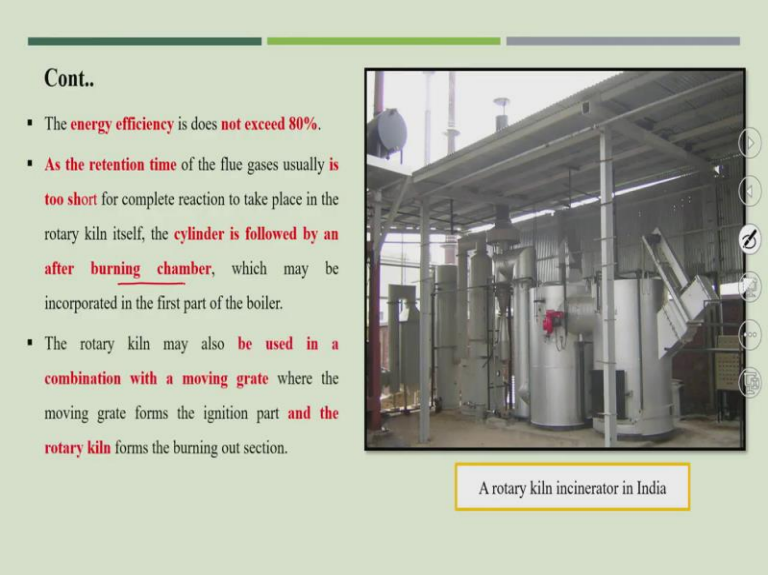

So the energy efficiency does not exceed 80% that is I think is ok but still is acceptable. So as the retention time of the flue gas usually is too short for complete reaction to take place in rotary kiln itself. The cylinder is followed by and after burning chamber which may be incorporated in the first part of the boiler. So that is one of the point very important point for the Rotary kiln because combustion time or retention time of the waste into the Rotary cylinder is short for complete combustion of the entire waste.

So if you are providing burning chamber it is more beneficial. So because of that only rotary kiln may be used in combination with the moving grate where the moving grate from the ignition part and the rotary kiln from the burning out station means I think this is the one of the very good

idea about combination of the two technology. The first technology for the first composition for the incineration of the material solid material will be inside the moving grate furnace.

And whatever the combustible gas is coming out or combustion gas is getting converted into the rotary kiln, I think that because in the moving grate also you will be required second combustion chamber is required. This combustion chamber could be a rotary kiln system.

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So this is another photograph of rotary kiln this is in Haryana India this is incineration facility. This is another from the Saudi Arabia.

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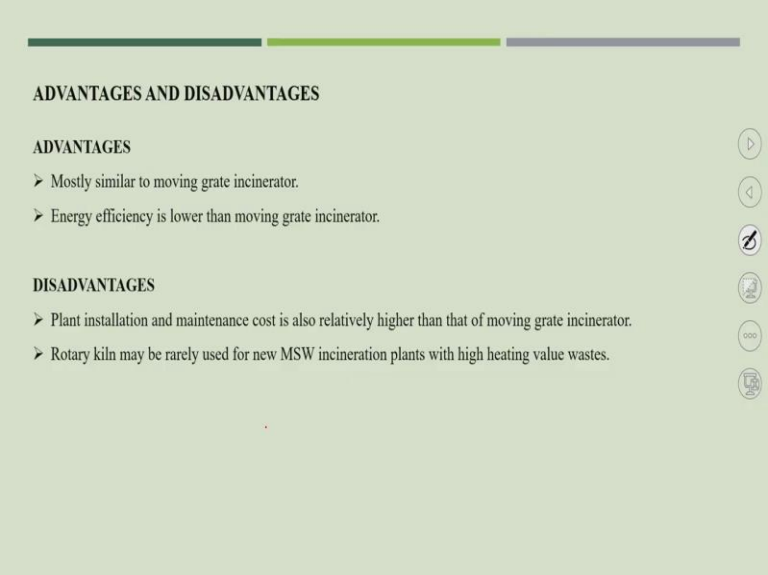

Now advantage and disadvantage: Advantages are mostly similar to the grate incineration energy efficiency is somewhat lower than the moving grate incineration. Disadvantage is same way like moving grate system the incineration and maintenance cost is relatively higher, and rotary kiln maybe rarely used for the new MSW incineration plant with heating value waste. I think this is a kind of rotary kiln is good to be used as a second combustion chamber for the combustion air which will have low heating value.

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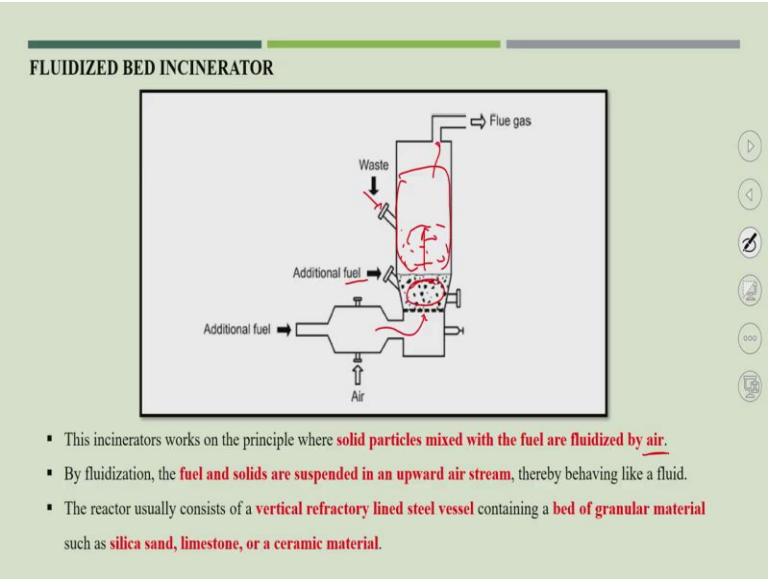

Now next is the fluidized bed incineration. So as the name suggests it is fluidized bed. So inside incineration, there will be a bed which will get fluidized and the entire waste also will be in fluidized condition. So here is the line diagram of that for style explain the line diagram. So here

waste is getting fitted into the vertical chamber. Now here this is the fluidized bed, and from the bottom the air is added and whatever the waste is added into the air getting feed into the chamber.

The waste will be in the fluidized condition because air is getting supplied. So this is your combustion chamber, and whatever gases will come out that will come out in flue gas form, and there is facility for putting some additional fuel for the combustion to increase the efficiency of the combustion. The incineration works on the principle where solid particles mix with the fuel are fluidized by air. By fluidization the fuel and solids are suspended in a upward air steam there by having behaving like a fluid fuel and solids.

These entire solids will be suspended for upward air stream. The reactor usually consists of a vertical refractory lined Steel Vessel Containing a bed of granular material like silica sand, limestone is some kind of ceramic material. This is a bed of granular material.

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The fluidization of the bed is ensured by air injection through a large number of nozzle in the bottom of incineration causing a vigorous agitation of the bed material in which the incineration of waste will take place in a close contact with the bed material in combustion air allowing relatively low excess air travel and high thermal efficiency up to 90%. So here the small nozzles will be available from there air is getting supplied.

So that the entire solid material will be in the suspended phase so suspended this entire area of the material is available for the combustion because of that the thermal efficiency is very high and this kind of technology this is one of the initiation bed. You can see here is a vertical vessel in Japan. This is in US, a fluidized bed incineration facility. I think this kind of Technology has never has been used for MSW.

But special kind of material because this kind of technology required for very special kind of material, meaning to say, I think this technology requires homogeneous kind of material. So in Japan or USA they use this kind of technology specially for the special agricultural residues that is more homogeneous in nature or in the municipal area sewage sludge dry swage sludge is highly combustible and because this kind of countries are very developed countries and these countries are having the large number of sewage treatment facility.

and because of that large amount of sewage sludge is getting produced. So this kind of technology is very useful because that material should be fluidized with the air. So we understand that this kind of technology cannot be used for the very large particle first thing and not heavy particles also we can put into the search kind of combustion facilities.

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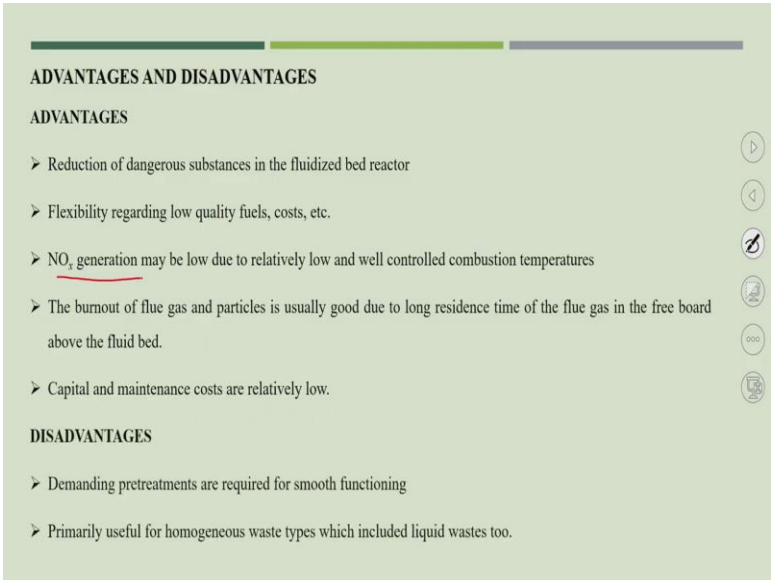

Now there are a lot of advantages which highlights the benefits of this technology. I think specially with the NO x generation that NO2 and NO3 our NO production is low as compared to both the technology that is the major problem with the moving grate and rotary kiln facility, and capital and maintenance costs are also relatively low. I am putting it into disadvantage, but that is a prerequisite of fluidized bed incineration facility depending on pretreatment are required for the smooth functioning.

So that is the reason, I put it in the disadvantages for that is a prerequisite for the such kind of technology primary useful for homogeneous waste type which includes liquid waste also because that will also could be fluidized into the air.

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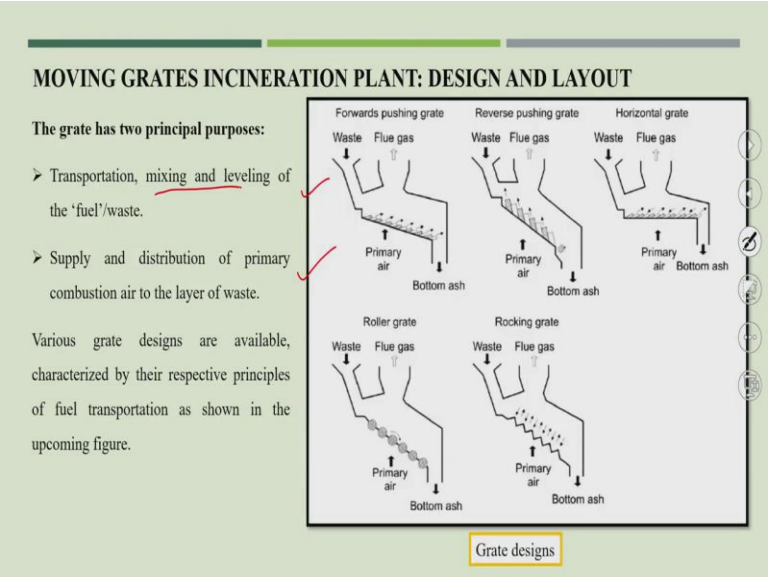

Now moving grate incineration plant design and layout: The grate has two principles. There is the major design point a design idea behind the moving grate incineration facility. That is the grate. Grate has two basic principle purposes transportation mixing and leveling of fuel or waste. And supply and distribution of primary combustion air to the layer of waste that is the two major principles of the grate.

First is the transportation and mixing and leveling of that particular waste material into the furnace area and supply and distribution of primary combustion air to the layer of the waste so that the proper combustion could be possible. Various grate designs are available characterized

by their respective principal of fuel transfer as shown in the coming figure. So these are the different kind of moving grates. So this is the grate ok.

This is the forward pushing grate as you can see here. This is the one kind of grate. This is reverse grate. This is going upward this is fixed. So similar way horizontal grate this is Rotary one, here the rotors are there and from the Primary care combustion air is adding through the small nozzles from the grate and waste is getting transported, and also getting combusted also this is another rocking grate. So these are different kinds of grates available and I think numbers are different from private companies also install the combustion facilities by using the different kind of grates.

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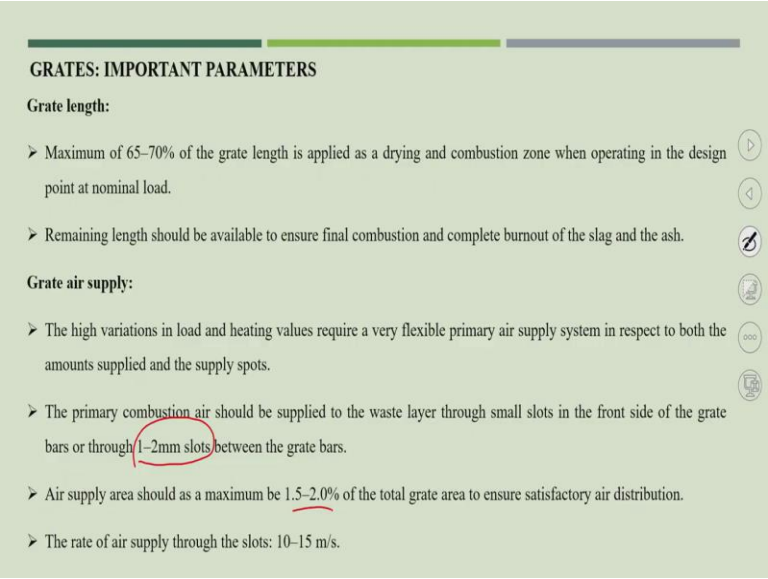

Grates important parameter the grate length maximum of 65 to 70% of grate length is supplied is and drying and combustion zone when operated design pointed nominal load. Maximum of 65 to 70% of grate length is applied as a drawing and combustion zone that 100% of grate. Remaining length should be available to ensure the final combustion and complete burn out of the slag and ash that is the very good idea about to finalize the proper length of the grate. So that 65 to 70% that means two third of area is required for proper combustion remaining on one third of area will ensure the final composition of complete burn out of the remaining material.

Grate air supply the high variation the load heating value required a very flexible primary air supply system in respect to the both amount supplied in the supply spots. The primary combustion air should be supplied to the waste layer through small slots in the front side of the grate bar or through this is the size of the slot on that opening 1 to 2 mm between the grate bars and air supply area should be maximum of 1.5 to 2% of the total grate area to ensure satisfactory air distribution and air supply through the slot that is 10 to 15 meter per second the velocity of that particular air supply through the grate into the waste.

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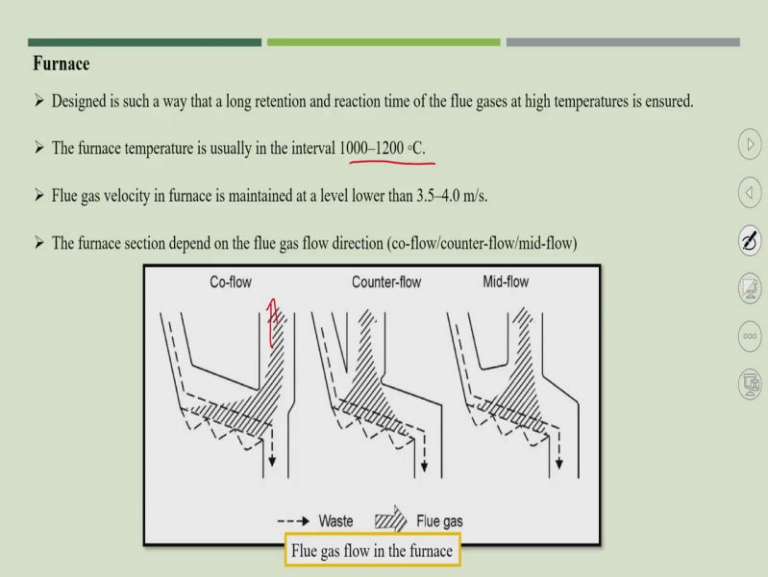

Now about the furnace the design in such a way that long retention and reaction time of the flue gas at high temperature is ensure. The furnace temperature usually as the interval of 1000 to 1200°C, but I think minimum temperature in the first combustion chamber has to be maintained at 850 degrees centigrade and second combustion chamber around 1100°C temperature has to be maintained in to the furnace.

Flue gas velocity in the furnace is maintained at a level lower than 3.5 to 4 meter per second. Whatever flue gases are generating generated in the furnace and furnace section depends on the flue gas flow directions. This is the combustion chamber, so this is the one way of flue gas flow direction is the counter flow this is a mid flow. Here we are not going to discuss much onto the Furnace design and all because I already told that this course is for the environmental engineers.

So, I will just talk about to what kind of flue gas will be produced and how best we can treat that particular flue gas.

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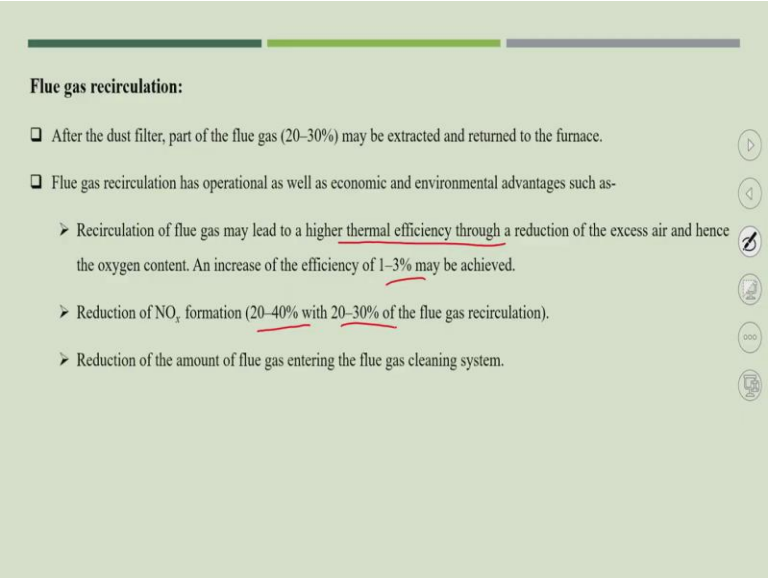

This is one slide. I put it specially because many countries are utilizing such kind of facility because for combustion will be required large amount of primary air. So can it possible that flue gas because already heat is there in the flue gas can that flue gas can be used for the primary air not 100% by at least 5% 10% 50% this flue gas can be recycled or recirculation could be possible into the furnace.

After the dust filter part of the flue gas that 20 to 30% may be extracted and returned to the Furnace through gas recirculation operated as well as economic environment advantages such as because by recirculation flue gas can lead to the higher thermal efficiency, ok because already the efficiency of 1 to 3% may be achieved because already this flue gas will have the temperature with that particular gas.

And reduction of NO x formation: This is one of the very important benefit that 20 to 40% with 20 to 30% of flue gas recirculation 20 to 40% reduction could be possible into the for the NO x formation. Reduction of the amount of flue gas entering the flue gas cleaning system obviously the amount reaching to the flue gas treatment facility will also get reduced.

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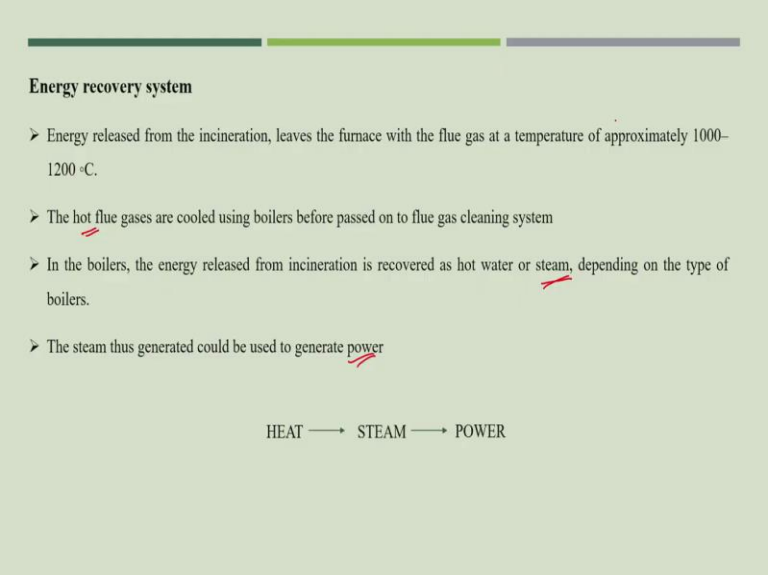

Now the energy recovery system, the energy released from the incineration leaves the furnace with the flue gas at a temperature of approximately 1000 to 1200°C, see the temperature of the flue gas, the hot flue gases are cooled using the boiler before passing onto the flue gas cleaning system. In the boiler the energy released from the incineration is recorded in hot water or steam, depending on the type of the boiler and the steam could be used to generate power. So I will get three different products is the first is the heat. This heat will get produce and next steam will get produce hot water or steam.

and from this team we can generate power of the power from the energy recovery. So heat steam and power there are three different products will come up normally when you talk about waste to energy facility waste to energy people will think that energy means power. So it is not only that energy is a power energy, it could be heat energy, it could be steam energy, it could be power also. So there is a possibility is that number of companies especially food processing industries are metal Industries required lot of heat or some industries requires steel.

So rather than producing power directly why not the heat is getting directly supplied to the processing industries and why not the steam is getting supplied to the food processing industry, which is required steam. So in developing countries what they did they installed Inception facility in such locations where these kind of industries are present. So, rather than power

production efficiency of power production is very low very poor. So, why not; this kind of two products the heat of steam getting supplied to such industries.

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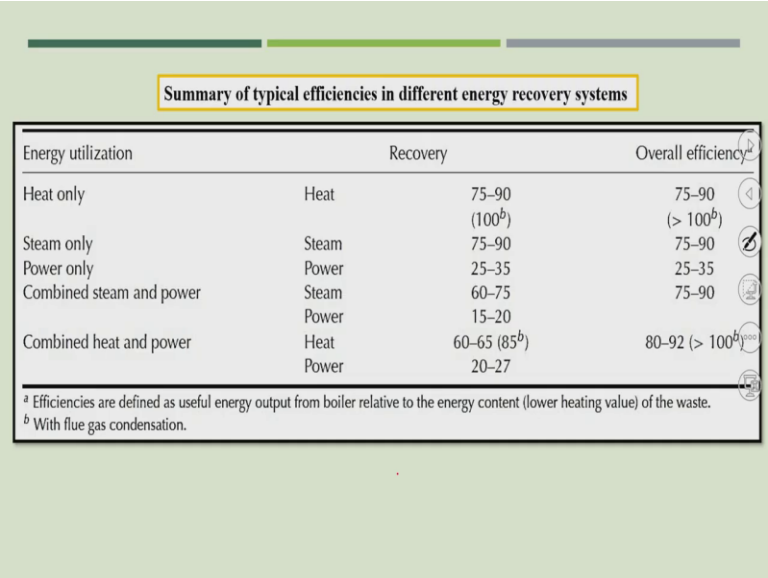

Summary of typical efficiencies in different energy recovery systems

Energy utilization	Recovery		Overall efficiency
Heat only	Heat	75–90 (100[b])	75–90 (> 100[b])
Steam only	Steam	75–90	75–90
Power only	Power	25–35	25–35
Combined steam and power	Steam	60–75	75–90
	Power	15–20	
Combined heat and power	Heat	60–65 (85[b])	80–92 (> 100[b])
	Power	20–27	

[a] Efficiencies are defined as useful energy output from boiler relative to the energy content (lower heating value) of the waste.
[b] With flue gas condensation.

So this is one is a very important table that summarizes the typical efficiency in the different energy recovery system. Suppose we were planning for power production only from the waste to energy plant incineration facility and power production is only the if the 25 to 35% recovery and efficiency is only 25 to 35% so you can understand if you are planning only for the power production is not that beneficial.

But if you compare with steam and power production the efficiency goes to 75 to 90% and specially when you are planning for heat and power combination of heat and power then see the efficiency 80 to 92% efficiency could possible. But in this case also the power efficiency is low. But the heat efficiency sees 60 to 65%. So there is always beneficial to plan or to install the incineration facility for planning of not on the production of power but also plan in a steam or heat along with the power production.

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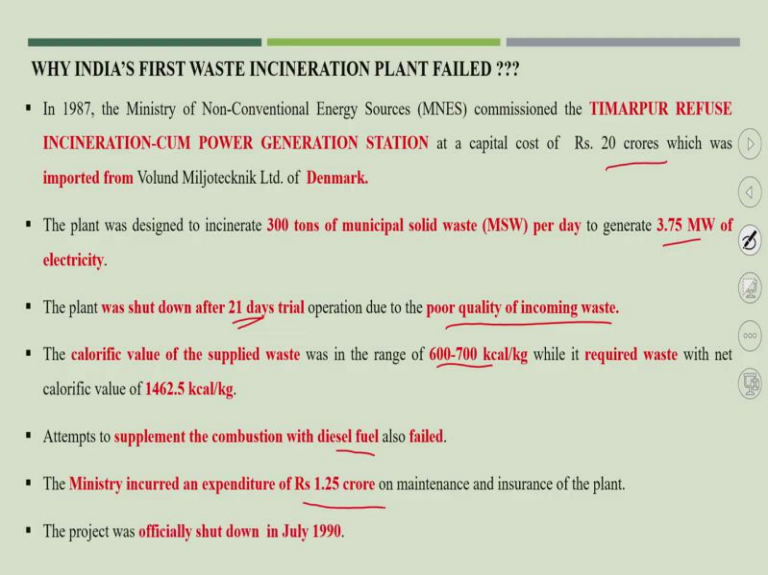

So here I come up with the one slide to just explain. India's first waste incineration plant in 1987 the ministry of non conventional energy sources that commissioned Timarpur Refuse incineration cum power generation station. In the Timarpur, Delhi and at a capital cost of 20 crores you can see that in 1987 the cost was 20 crores the capital cost, and that particular Technology has come from the Denmark.

The plant was designed to incinerate 300 tons MSW per day to generate 3.5 megawatts of electricity. The plant was shut down after just 21 days' trial, trial was failed after that has shut down the complete incineration facility because of poor quality of incoming waste. See in 1987 1997 even up to 2000 if you see the waste composition, I showed it in the previous lectures the composition of in Indian waste was mostly the biological in nature.

Those days the biological components used to be a 60 to 70% and more and everything was the mixed. There was no segregation because of that very poor quality of incoming waste used to be received in this incineration facility. Calorific value of the supplied waste was in the range of only 600 to 700 kilo calorie per kg. But required was calorific value was around 1500 kilo calorie per kg the required calorific value attempt to supplement the combustion with diesel fuel.

Diesel fuel even coal fuel also has been added to get the proper combustion temperature, but finally they put a lot of money for maintenance and running of that particular plant. Finally, the project was officially shutdown in July 1992 within 2-3 years that is completely shut down.

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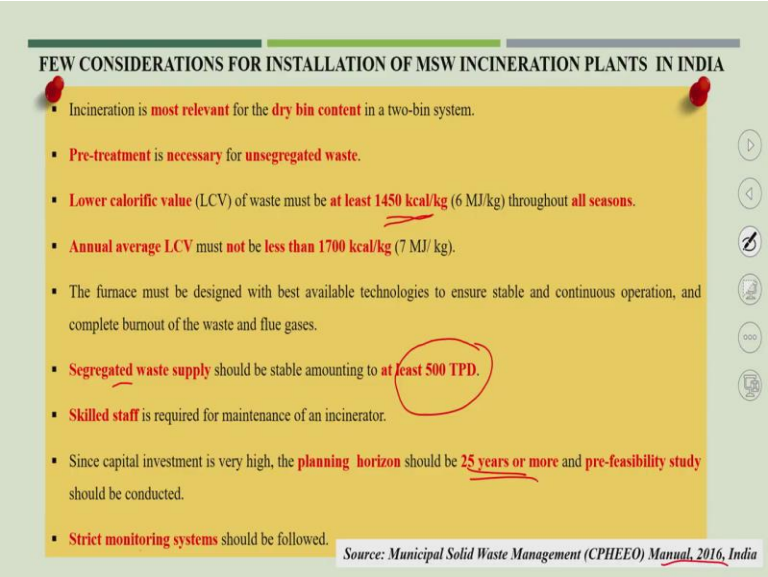

I think I will come up with the few more case studies in the last lecture of the incineration. Because recently we have come up with some more incineration facilities in India and even I think we need to know some of the case studies about the European incineration facility, especially Japan is good for the into the incineration facilities. So I think one of the case studies will come up with the in one of the lecture.

So I think I am left with two slides. The last two slides on few considerations for incineration of MSW incineration plant in India. I think incineration is most relevant for the dry bin content in 2 bin system. So that is from the manual 2016. Pretreatment is necessary for un-segregated waste but I think if AC is already segregated its source no need of pretreatment lower calorific value 1450 kilo calorie per kg throughout all the season so that is the important consideration.

So all the seasons, specially in the rainy season also need to have this kind of calorific value and that is lower calorific value or less value calorific value, N1 that must not be less than 1700 kilo calorie per kg annual average. The Furnace must be design with best available technology to

ensure a stable continuous operation and complete burn out of the waste and flue gas segregated waste supply should be stable amount at least 500 tons per day.

See the segregated waste supply should be 500 tons per day capacity. I think only the city is having large amount of waste generation. Say suppose cities like Kolkata Delhi Mumbai Hyderabad Bangalore Jaipur such kind of cities which are producing 2000 per day waste or more than that so such kind of cities only can come up with such large incineration facility. Skilled staff is also required that is also very important.

Since capital investment is high so planning horizon should be 25 years' operation or more is required before planning for installation of incineration facilities., and strict monetary system should be followed. This is specially for the flue gas monitoring system.

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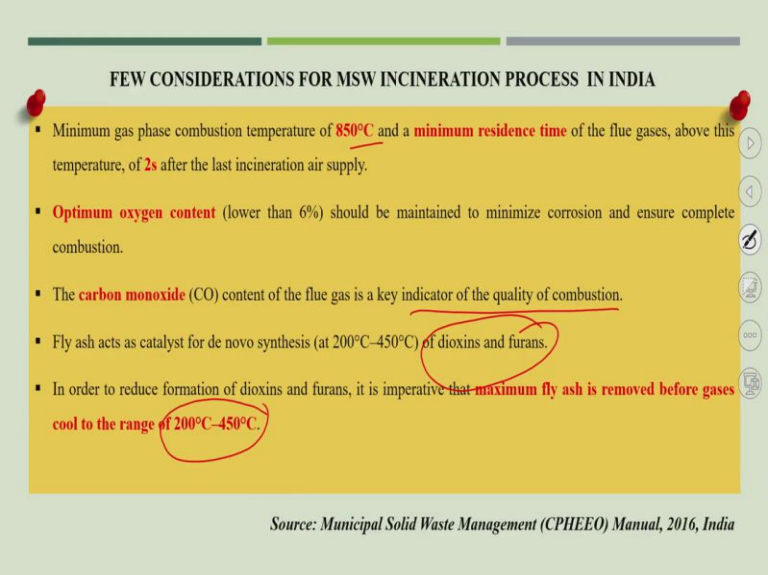

And few considerations for MSW another once how you install the incineration plant for the operation purpose? what are the considerations that are needed to be followed and minimum temperature which I have already talked about 850°C with response time of 2 seconds optimum oxygen content should be maintained for the combustion. Carbon monoxide container flue gas is a key indicator of the quality of the combustion.

This is properly for the monitoring system. Flue gas has acted as a catalyst for a particular synthesis of this is the important pollutant dioxin and Furans that standardization also has been given now in the monitoring system, this has to be monitored. How much is the production of dioxins and furans and in order to reduce the formation of dioxins and Furans the flue gas temperature has to be reach about 200 to 450°C means cooling of the flue gas is very important to further reduction of dioxins or furans.

So these are few consideration is given in the MSW manual and here I will finish this lecture. Now, I think once you understand the entire incineration facility, there are two major pollutants are coming out from the incineration one which as an environmental engineer, we need to understand one is the flue gas and solid residue. So in the next lecture we will go for flue gas treatment.

How best we can treat the flue gas and followed by solid residue also I think in one of the lecture I will talk about few case studies and also show that you people can understand incineration or chemical transformation of MSW, thank you.