Chemical Process Utilities
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Lecture - 24
Steam Generation Unit

Now next lecture is related to the steam generation unit. See in the previous lectures, and we discussed the different concept of steam and the basic philosophy for steam generation. We discussed the boiler's various aspects, the boiler's concept, and the integral part of the boiler, all these things we have discussed in the previous lectures. In this particular concept, we will first discuss the various components of the steam generation unit.

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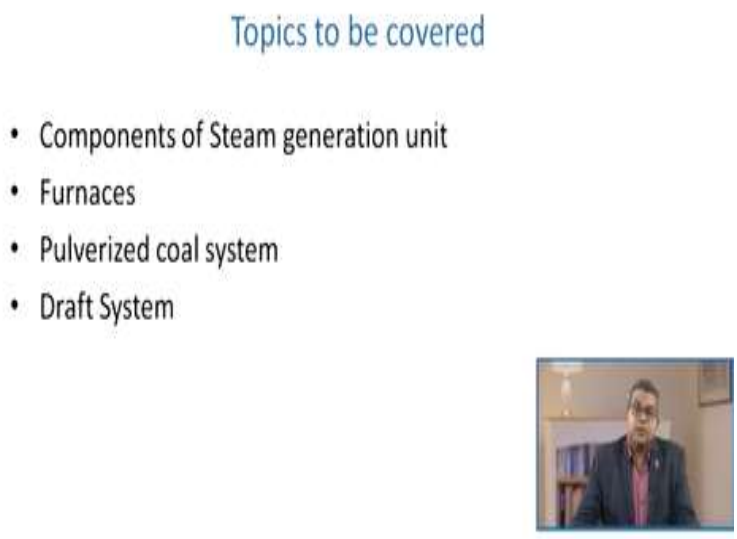

Then we will discuss the furnaces because the furnace is an integral part of any steam generation aspect. Since we require fuel and coal has a significant portion of all the fuel choices. Then we will discuss the pulverized coal system and draft system.

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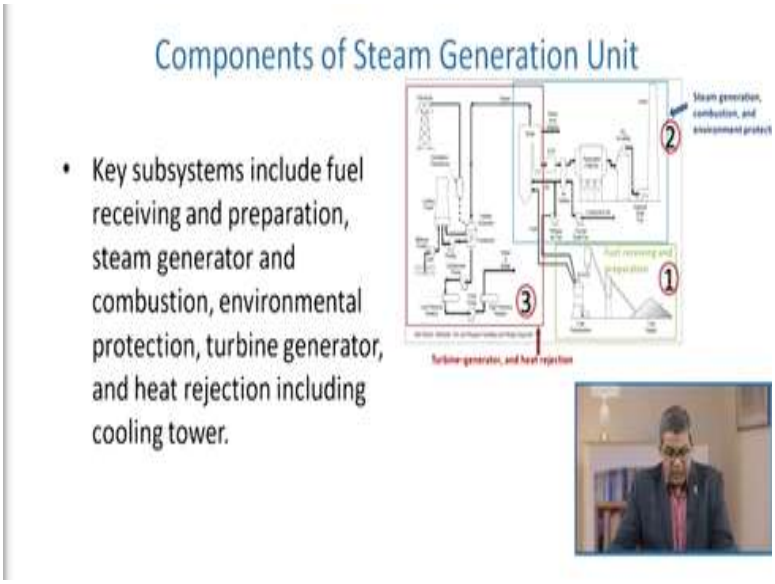

So, let us talk about the steam generation unit. See previously, and we discussed the boiler, different parts of the boiler, integral part of the boiler, classification of the boiler, and definition of the boiler. Now alone boiler cannot produce steam. So, you require various other allied parts accessories, different units like we discussed that fuel could not be used, especially coal. Because the coal usually, raw coal comes in lumps and other things.

So, you need to go for fuel preparation. After that, you need to go for some other allied functions before this fuel or water can become part and parcel of the steam generation now since this steam generation is based on the combustion of fuel. So, you cannot overlook the importance of various types of environmental protection activities because the flue gases can carry harmful gases and a significant quantity of heat.

So, all these things usually contribute to the basic definition of steam generation, and every unit has its importance. So, that is why when we talk about the steam generation unit. The key subsystems they are include they include fuel receiving and preparation. You may receive either fuel, natural gas, or the fuel may be oil or coal. Then different accessories and mountings apart from the boiler contribute to the concept of steam generation and combustion.

Then we must look into the environmental aspect, the turbine generators, heat rejection aspect, and cooling towers because sometimes you need to perform the heat recovery and go for the condensation and other channeling aspects. So, for this, the cooling tower plays a very vital role.

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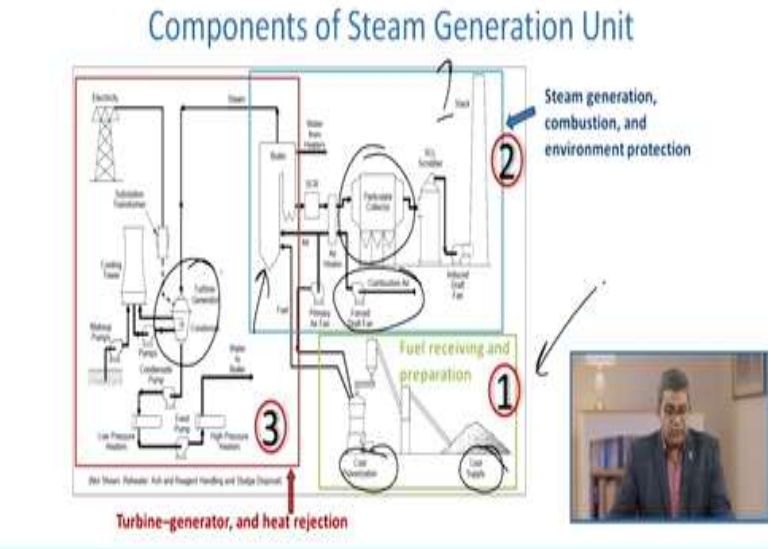

Here you see the different parts of the turbine generation heat rejection system. Here, you see that the fuel is received at the fuel receiving station. Is here, we are taking the example of coal. So, the coal supply then goes for the coal resting to be used as a fuel for the boiler system. Similarly, the environmental protection and environmental aspect here you are having boiler because as I told you that it is a combustion reaction.

Here you need an adequate air supply within a stipulated quantity and a flow rate. So, you have the combustion air with the help of a forced dart fan air heater, and it goes into the boiler. But when we perform the combustion reaction, there are two integral parts: the heat, and the second one is the various off-gases. Apart from this, we have some unburned coal. So, that is why you have various particulate collectors then scrubbing units.

And whatever is left goes into the atmosphere through the various treatment methodology. Another thing is that once you produce the steam, there are turbine generators because if you produce this steam, you will utilize this system somewhere. Now here we are taking the example of a steam

generator. Apart from this, steam can be used as sparging steam, and it can be used as a slurry preparation method. It can be used for mixing etc.

So, here is a steam generator for heating purposes. So, here is a steam generator, and see there are two, three different parts. One is that you are producing the power. The second is that you may produce some water that may get condensed in this way. So, you may have some condensate recovery lines because, again, I told you that water is a precious one. You have the cooling tower and make-up pumps. So, all these are some of the integral parts of the entire steam generation unit.

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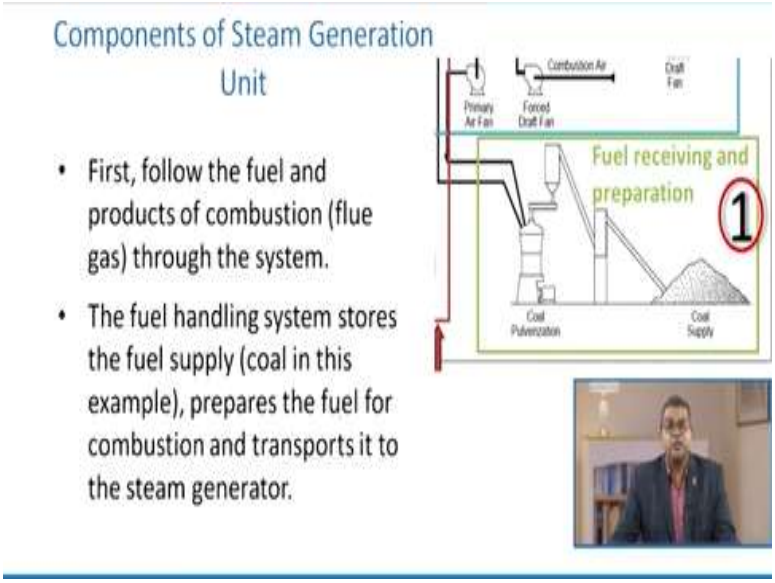

So, let us take them one by one. Because if you follow the fuel and a product of combustion through the system, the fuel handling system usually stores the fuel supply that is cool for this particular example. This prepared the fuel for combustion and transported it to steam generation as you know that we require some specific size in terms of coal.

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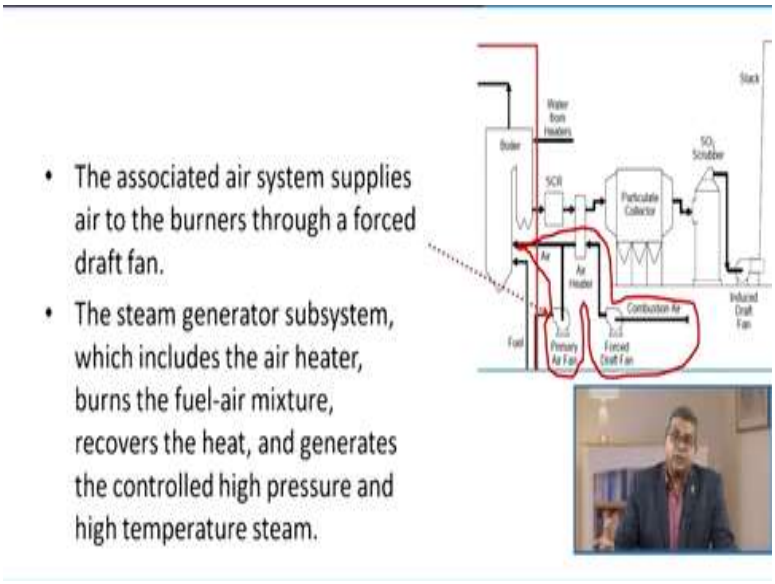

So, you can go for, say, polarization, grinding, etc., whatever is required for this one that is attributed to the fuel receiving and preparation section. When you have selected the fuel, you have dressed the fuel as per the requirement, and then the next aspect is the combustion air. Because it is a combustion reaction, you need to supply the air by utilizing the fact that it contains 21% of oxygen.

So, the associated air system usually supplies air to the burner through a forced draft fan here. Now the steam generator subsystem includes the air heater. Because normally, if you supply the normal air or atmospheric air, then definitely the efficiency of the boiler would be on the lower side. Because atmospheric air is roughly available at 25 to 30 degrees Celsius. So, you need to have some air heaters to minimize that temperature difference.

Then this the burns, it is here heater burns the fuel-air mixture to recover the heat sometimes it may be the source of heat to the air heater may be unutilized heat from the various processes. Then the generators those who are controlled high pressure and high-temperature steam. So, all this air contributes to this boiler subsystem.

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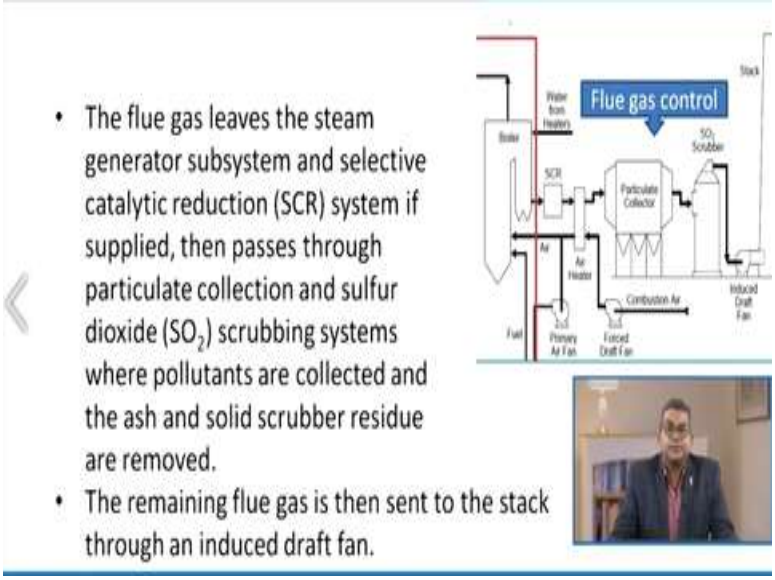

The next aspect is again very crucial, especially in the present-day scenario. If we have combustion, the combustible air or flue gas may contain unburned fuel, some undesired gases, etc. So, the flue gases those leaves from the steam generator subsystem or sometimes you may have selective catalytic reduction system if supplied then pass through a particular collection and sulfur dioxide scrubbing system.

Because, see in coal, apart from carbon, there may be a chance that a significant quantity of sulfur may present. Since we are performing the combustion reaction, a certain quantity of SOx may get generated over time, and you cannot discharge this to the atmosphere as such. Therefore, you must have some scrubbing unit to remove these SO 2 or SO 3 is formed in due course of time.

So, they are scrubbing units, and you can remove the sulfur in a scrubber residues form over some time. And there is a stick that discharges the remaining flue gas either through the induced dark pan, or sometimes it may be through the natural draft.

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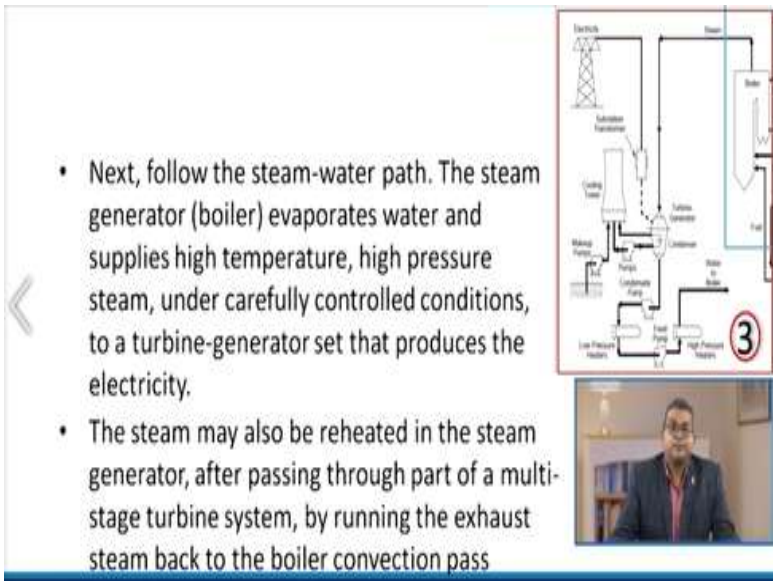

Now another very important thing is the steam water path. Because we are generating steam, the steam is being utilized somewhere in some process utilities. So, the steam generator that is a boiler here boils water and creates steam at high pressure. So, under the carefully controlled condition, which is essentially required for the boiler operation, it is sent to the turbine generator to produce the electricity or work whatever is required.

This steam may also be reheated in the steam generator after passing through the part of the multi-stage turbine system by running the exhaust system back to the boiler convection pass.

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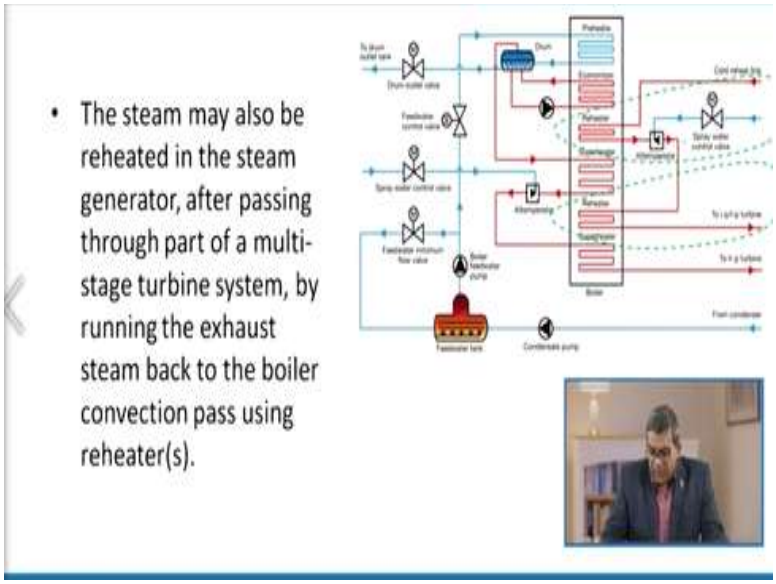

Apart from this, you may utilize whatever condensate is being formed as a source of feed water because sometimes this condensate is available at a substantially high temperature. So, it always enhances the boiler efficiency if we use it. Now see, when we talk about the steam, this may also be reheated in the steam generator. And if we pass through the multiple-stage turbine system, we can extract the work.

Now here you see that we have these pre-heaters superheaters, etc., to maximize boiler efficiency.

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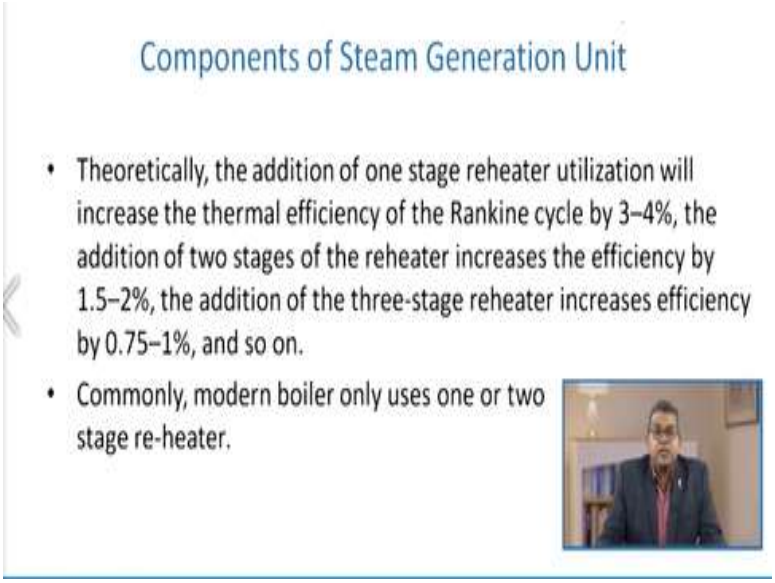

Now theoretically, the addition of one stage reheater utilization increases the Rankine cycle's thermal efficiency by 3 to 4%. Now the addition of two-stage of the reheater normally increases the efficiency, say by 1.5 to 2%. So, the addition of three stage reheater increases the efficiency by 0.75 to 1%. So, the modern boiler commonly only uses a one or two-stage reheating system.

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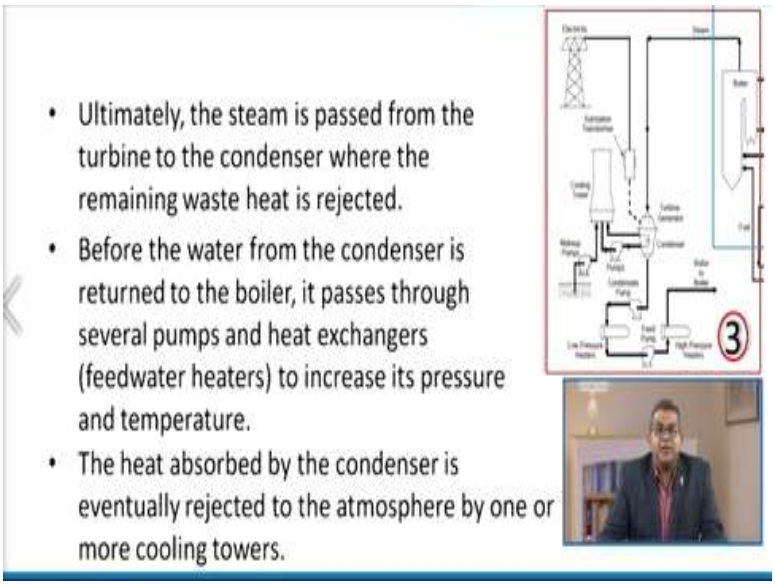

The steam is passed from the turbine to the condenser, where the remaining waste heat is rejected. Before the water from the condenser is returned to the boiler, it passes through the several pumps and heat exchangers that are the feedwater heaters to increase the pressure and temperature. Now heat absorbed by the condenser is eventually rejected to the atmosphere by one or more cooling towers.

So, this is the cooling tower, so whatever heat is being absorbed, it is rejected by the atmosphere but very controlled.

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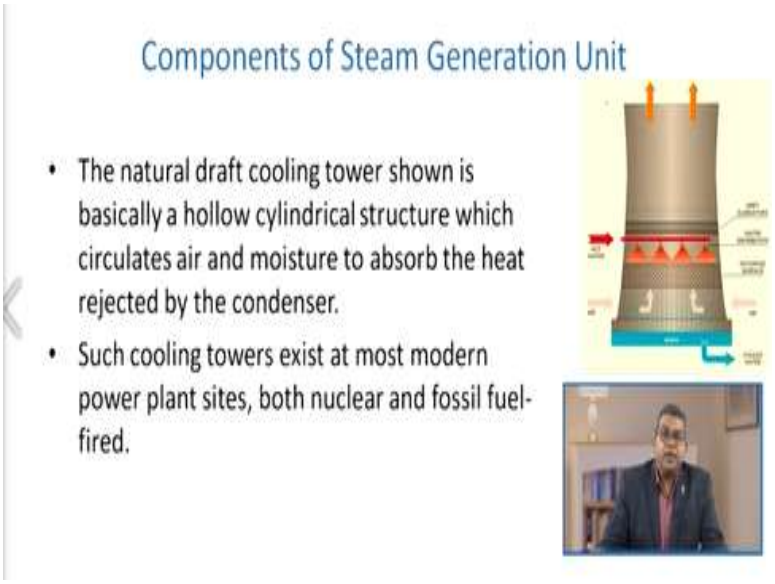

Now here, see the cooling tower. Again, the cooling tower is an important or integral part of any steam generation segment. So, there may be a natural aero force type of cooling tower. So, the natural type of cooling tower shown here is a hollow cylinder. This is a hollow cylinder that circulates air and moisture to absorb the heat rejected by the condenser.

Now here you see that the hot water supply and this draft eliminate the water distribution. So, here you are passing through to the air, and from the bottom part of this, the cooled water is being discharged, and it can be reused in the steam generation unit. Such cooling towers exist in most modern power plant sites, maybe nuclear or fossil fuel-fired.

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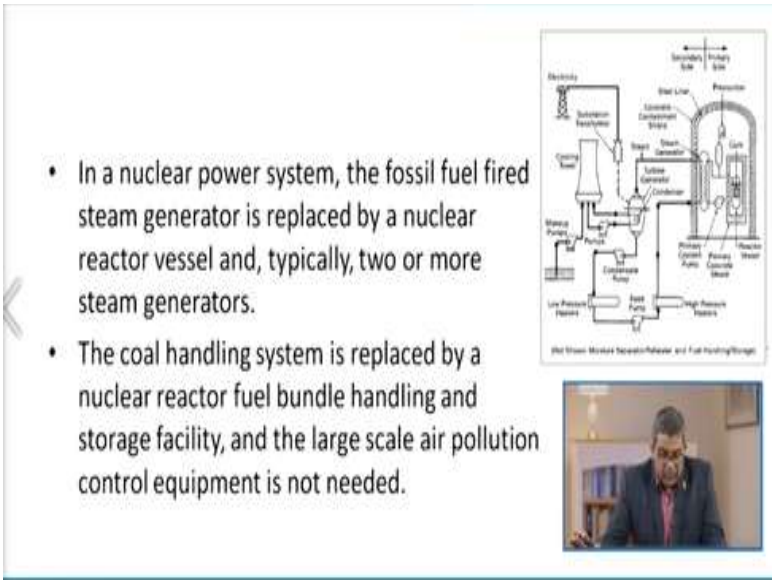

In the nuclear power system, the fossil fuel fired steam generator is replaced by the nuclear reactor vessel, typically two or more steam generators. This is what you can say about the supplement thing in the nucleophile reactors. The coal handling system is replaced by the nuclear reactor fuel bundle handling and storage facilities, and the large-scale pollution control equipment is not needed.

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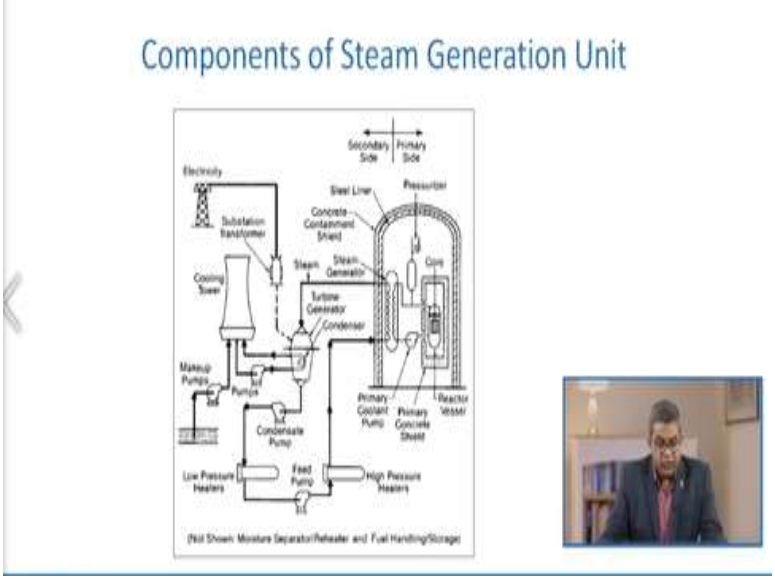

Here you can see that previously when we were discussing the steam boiler fired steam generation plant, here this is being replaced with a nuclear reactor. Now here you see that this is your nuclear reactor through which you are generating the heat for steam production. So, here this is a steam generator, and this is the reactor from which you are generating the heat to produce the steam over here.

Now, the chances of any pollution, especially atmospheric pollution, are negligible. So, the stakes and other particulate units have been replaced or removed from this particular junction. So, this is the basic difference between the nuclear reactor steam generation unit and the boiler type of steam generation unit.

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Now let us talk about the major components. The major components in the steam-generating and heat recovery system they are including furnace and convection pass, super steam heaters may be primary and secondary, steam reheaters boiler, or steam-generating banks.

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Economizer, steam drums, attemperator, steam temperature control system, and air heaters.

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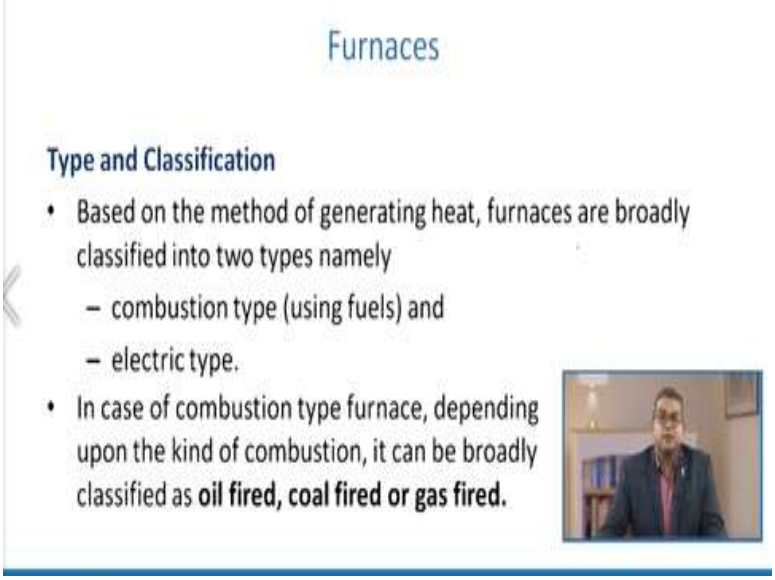

Let us talk about the furnaces because the furnace is the core of any boiler or steam generation unit. So, there are various types in the classes of furnaces; one is based on the method of generating heat. So, in this category, the furnaces are broadly classified into two types: combustion type, those that use fossil fuels, and the second one is electric type. Now in the case of combustion type furnace, depending upon the kind of combustion.

It can be broadly classified into oil-fired, a liquid phase; coal-fired, a solid phase and gas-fired, which is the gaseous phase.

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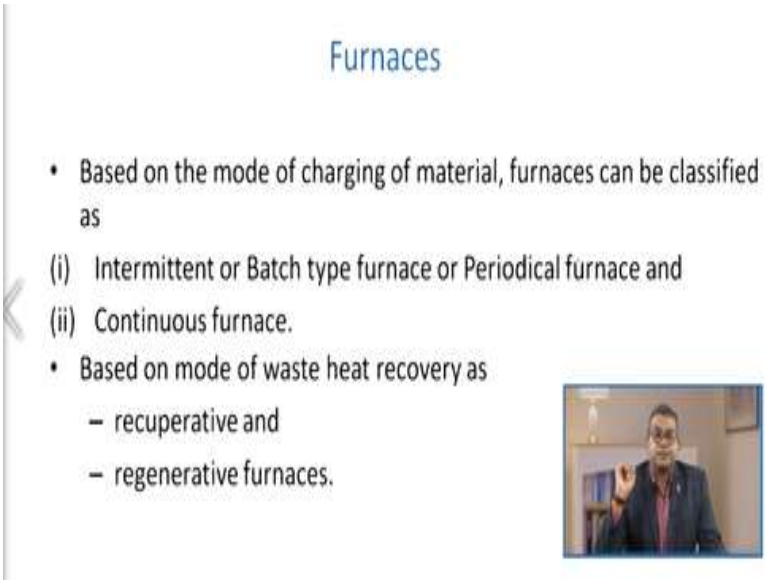

Another classification may be based on the mode of charging of material. These furnaces can be classified into intermittent or batch-type furnaces or periodical and continuous furnaces. Sometimes based on the mode of waste heat recovery, one is recuperative, and the second one is the regenerative furnace.

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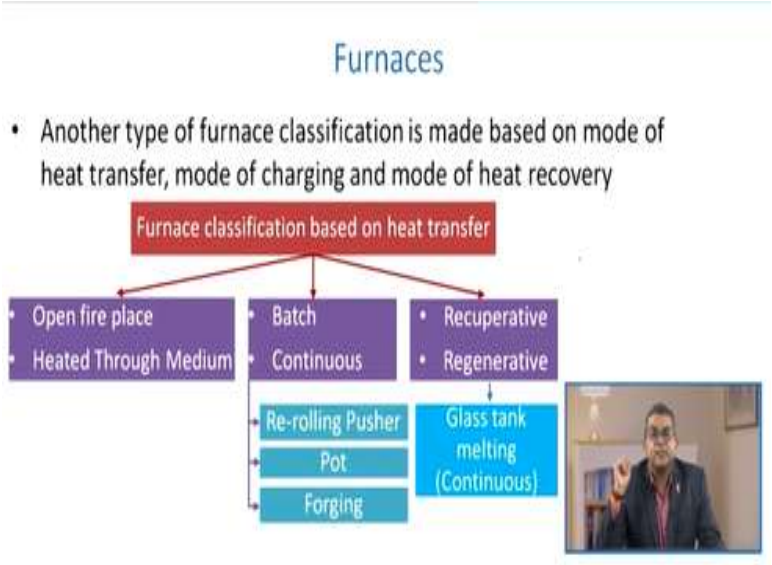

Another type of furnace classification is based on the mode of heat transfer, method of charging, and heat recovery. So, here you see that the furnace classification is based on heat transfer. One is based on the open fireplace, and the second one is heated through the medium. Another classification batch or continuous is then recuperative and regenerative. Further, this classification is classified into the re-rolling type of pushers, pot, forging, and recuperative and regenerative type glass tank melting continuous operations.

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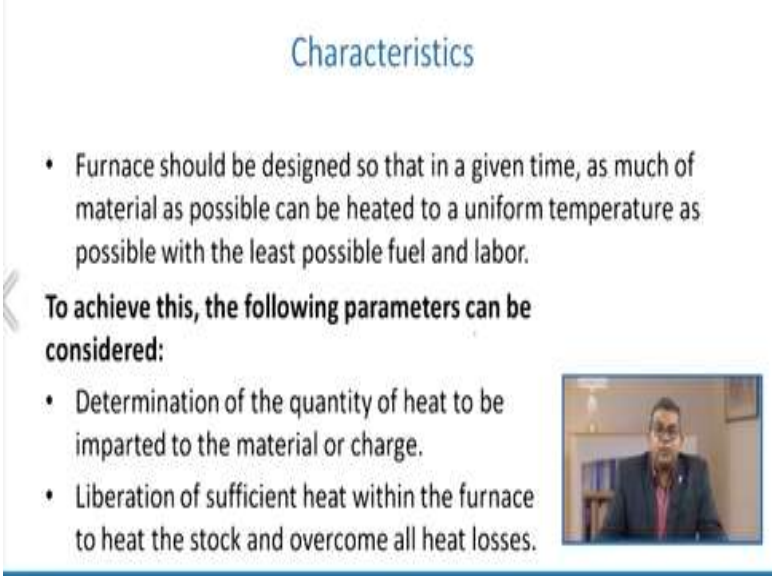

Now furnace should be designed in such a way so that in a given time, as much of as material is possible can be heated to a uniform temperature as possible with the least possible fuel and label that is essential for the economics of the boiler or steam generation unit. Now the question arises of how to achieve this? So, to achieve this, certain parameters need to be considered. One is determining the quantity of heat to be imparted to the material or charge.

That depends on the steam requirement, the other parameters that how much temperature you require, and the pressure you require, so all these things are interlinked. Then another parameter that needs to be considered is the liberation of sufficient heat within the surface to heat the stock and overcome all heat losses.

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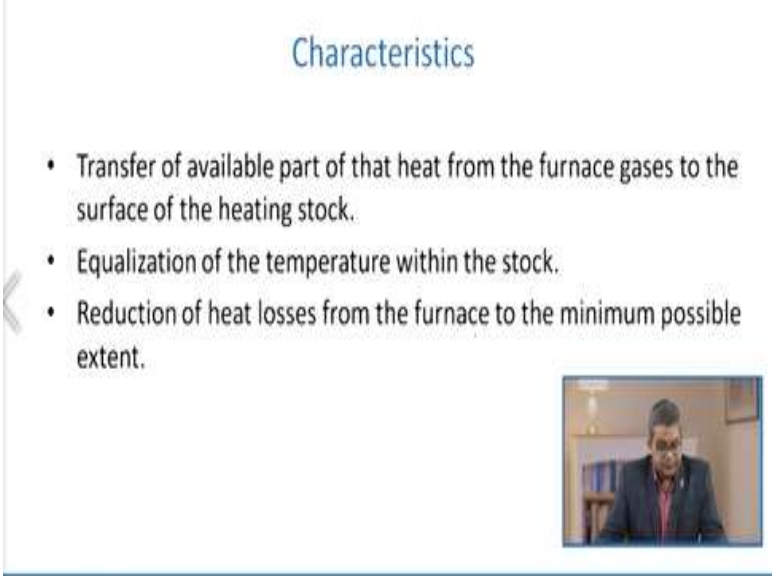

Another part is the transfer of the available part of that particular heat from the furnace to the surface of the heating stock. So, any kind of lagging is always undesirable. Then equalization of a temperature within the stock is another consideration and the reduction of heat losses from the furnace to the minimum possible extent. See, there are various approaches, and there are three basic modes of heat transfer from the furnace: conduction, convection, and radiation.

So, these furnaces must be designed in such a way to reduce any kind of heat loss attributed to these modes of heat transfer.

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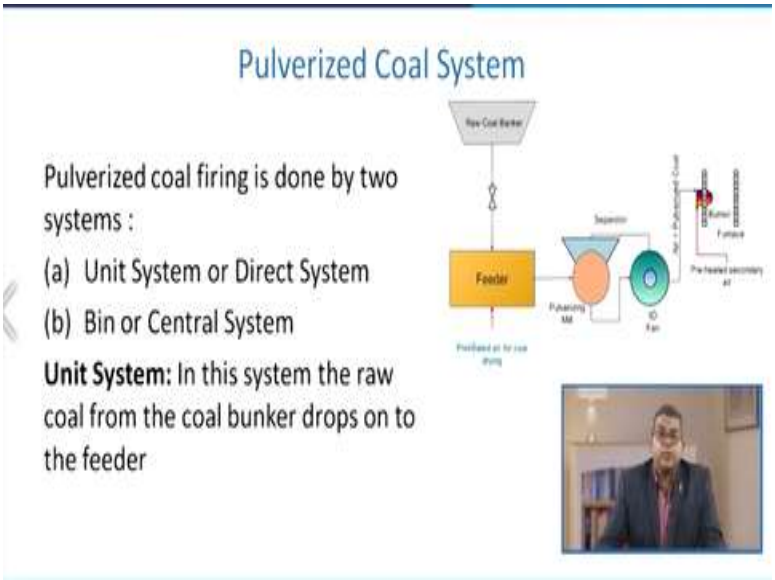

Now let us talk about the pulverized coal system. We have already discussed the concept of polarization in the previous lectures. So, pulverized coal firing is usually done by two systems, one is the direct system or called a unit system, and the second is the central system or bin type. The raw coal from the coal bunker drops into the feeder in the unit system. That is the raw coal bunker, and it is a feeder. And then this is a polarizing mill, and through this, it goes to the desired station.

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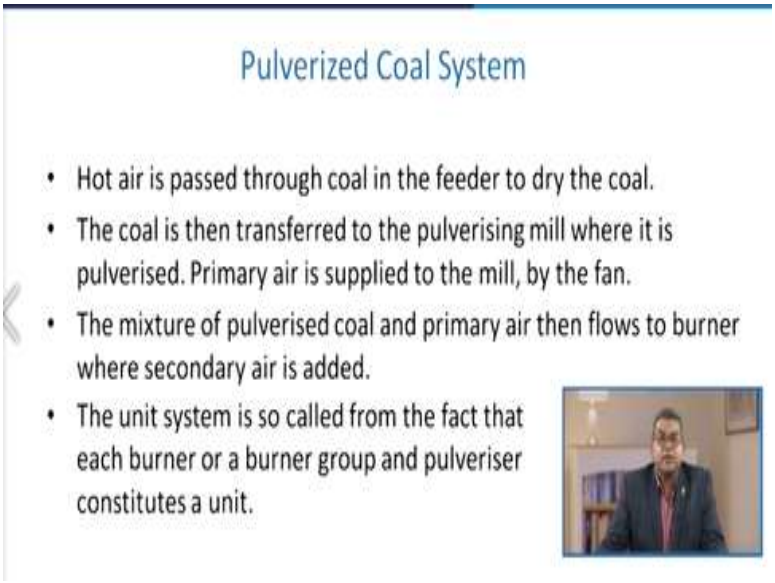

The hot air is usually passed through the coil in the feeder to dry the coal. Sometimes the moisture or sometimes because of the mining issues, this may be wet during the use. Now the coal is then transferred to the pulverizing mill; here, you see that this is the pulverizing mill where it is pulverized, and in between, you need to supply the primary air to the mill by the fan. Here you can see that fan is supplying the primary air.

The pulverized coal and primary air mixture flow to the burner, where secondary air is added. Now here you see that this is transported to the burner. Now the unit system is so-called because each burner or burner group and pulverizer constitutes a unit. So, you can say this is an entire unit.

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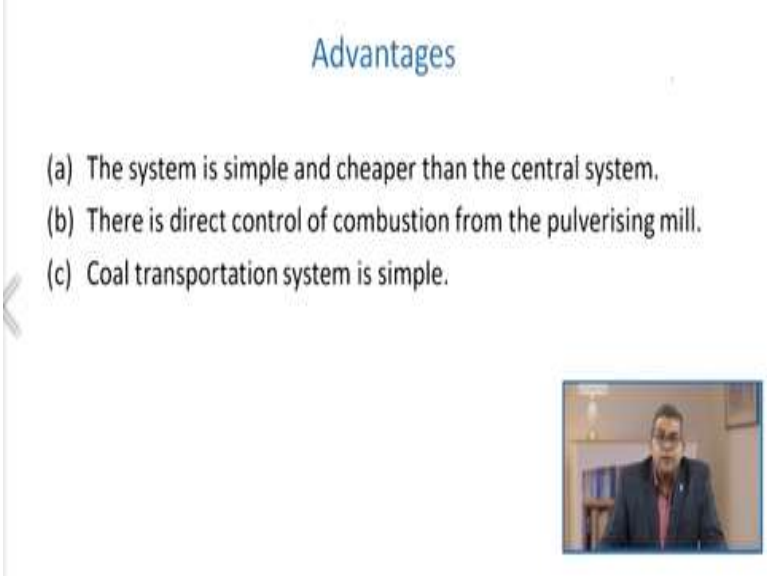

Now there are various advantages attributed to this type of system. The system is simpler than the central system for the direct control of combustion from the pulverizing mill. Now the coal transportation system is extremely simple.

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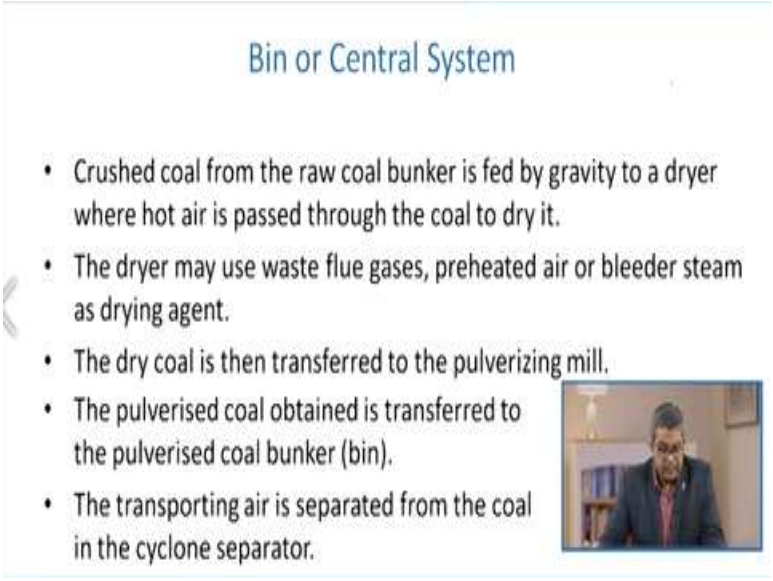

Now let us talk about the bin or central system here. The crushed coal from the raw coal bunker is fed by gravity to a dryer, where hot air is passed through the coal to dry it. The dryer may use waste flue gas to preheat air or bleeder steam as a drying agent. This dry coal is then transferred to the pulverizing mill, and the pulverized coal obtained is transferred to the pulverized coal bunker called a bin. The transporting air is separated from the coal in a cyclone separator.

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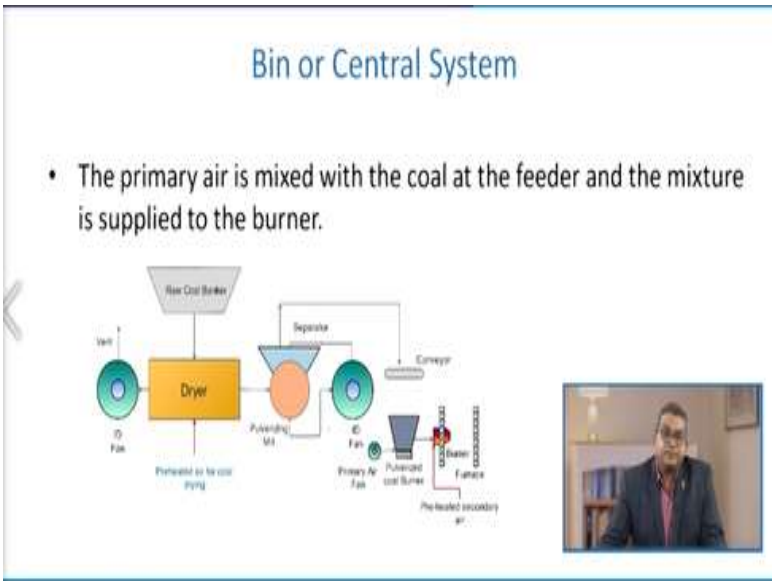

Now here you see that this is the raw coal bunker dryer, which is the pulverizing mill, and to this, it is conveyed to the desired station. And here you see that we have the primary fan, and this pulverized coal burner is subjected to the furnace. Now here you are mixing the primary air in the system to have combustion properly.

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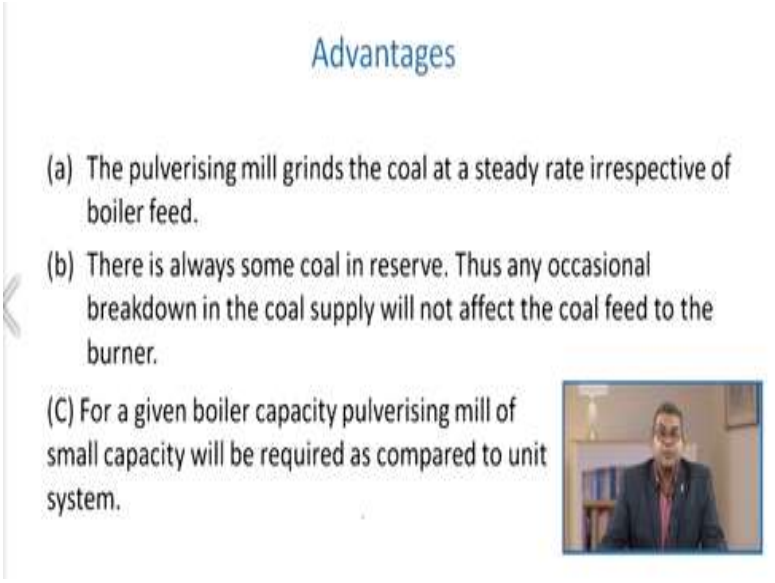

There are again various advantages attributed to this central system. The pulverizing mill grinds the coal steadily irrespective of boiler feed. There is always some coal in reserve; thus, any occasional breakdown in the coal supply will certainly not affect the coal feed to the burner. And sometimes it is quite common that because it is being transported through the rail system, etc., any

kind of disruption in the coal supply sometimes may cause a problem to the regular steam generation.

For a given boiler capacity pulverizing mill of a small capacity may be required compared to the unit system.

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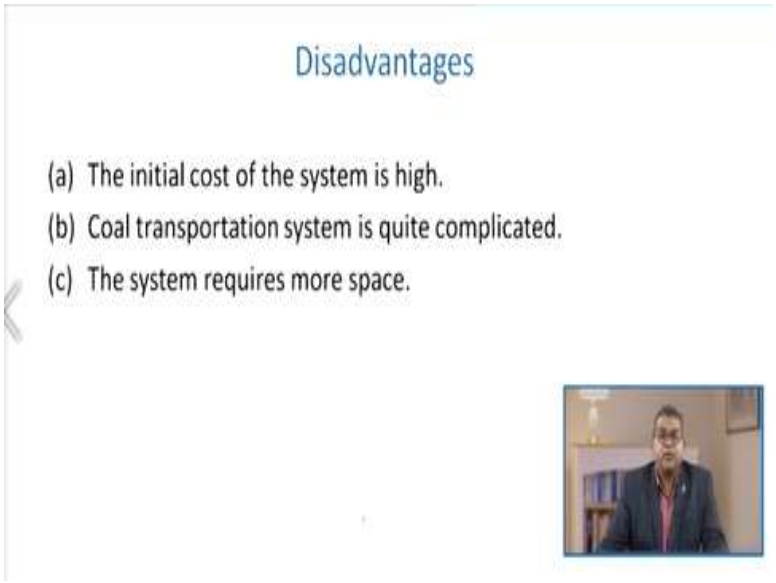

So, this is these are the advantages. But when there are advantages, there are certain disadvantages too. One of the disadvantages is that the system's initial cost is high. There are various units associated with this one. It is not a single unit. So, the initial cost of the system is high. So, initially, you may experience that cost of your steam generation is or per unit cost of the steam generation is on the higher side.

Then the coal transportation system is again very complicated. As you see in the figure, this system requires more and more space. So, when we talk about the other aspects of plants in totality, this again contributes to economics.

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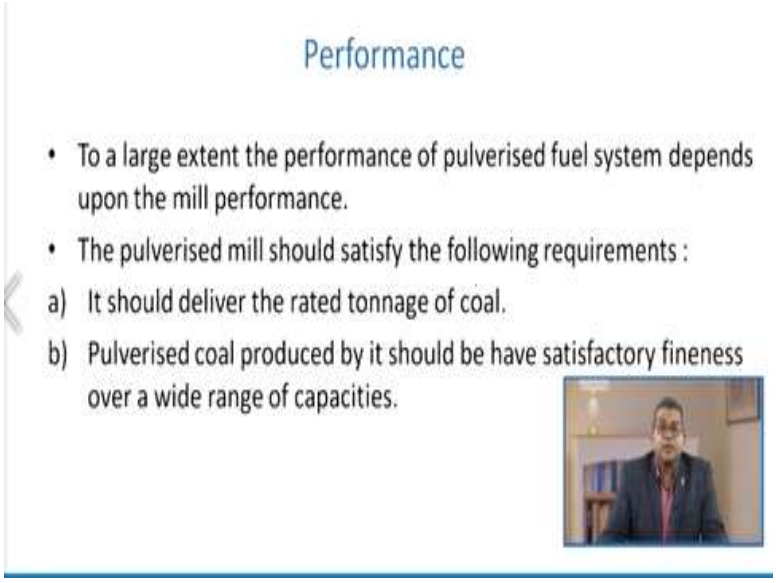

Let us talk about the performance. To a large extent, the performance of pulverized fuel system depends upon the mill performance. Now the pulverized mill should satisfy the different requirements. One is that it should deliver the rated cargo of coal. It is one of the foremost requirements, and its pulverized coal should have satisfactory fineness over a wide range of capacities. So, you must have desired fineness or particle size before it goes to the furnace.

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Apart from this, it should be quite an operation because sometimes noise may create a problem and power consumption. It consumes a significant quantity of power, so its power consumption should be low, and the mill's maintenance cost should also be very low. So, the per-unit cost of

steam can be reduced substantially. For this, you may require certain equipment, especially both for the unit and a central system of pulverized coal handling plant.

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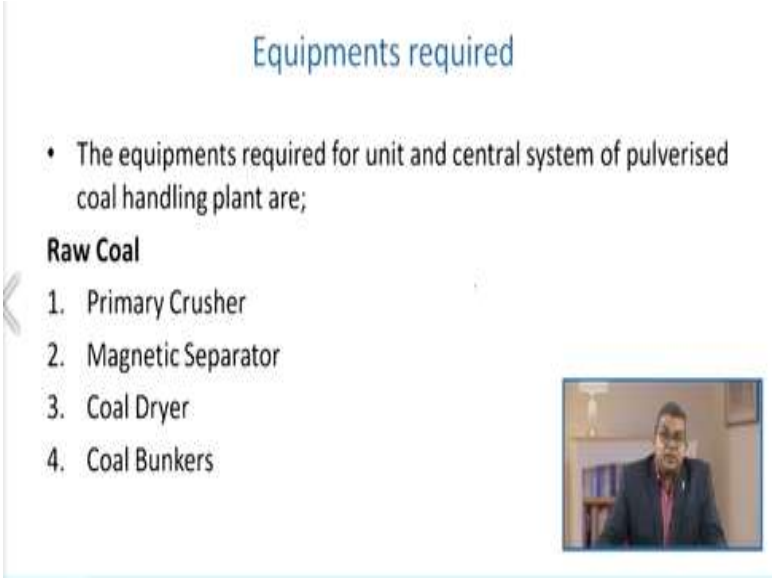

You require the primary crusher for raw coal because it usually forms in a big lump. Then magnetic separators because some metal, especially iron impurities, can be removed a priory. You must have a coal dryer; we have already discussed that it contains a significant quantity of water and moisture. So, before it goes to either pulverization or furnace, it should be dried and must require the coal bunkers.

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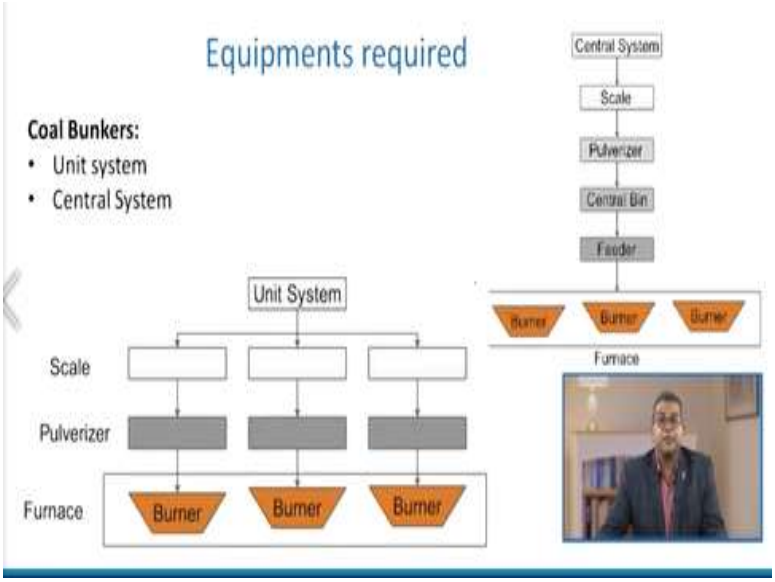

Now here you see the coal bunkers both for the unit and central systems. Now here is your unit system. It would help if you had the scale then the different pulverization units, and it goes to the burner, and you may have different burners. Here in the central system, you must have a scale, then perform the pulverization operation goes to central bin, feeder, and through the feeder, it goes to the different furnaces through the burner.

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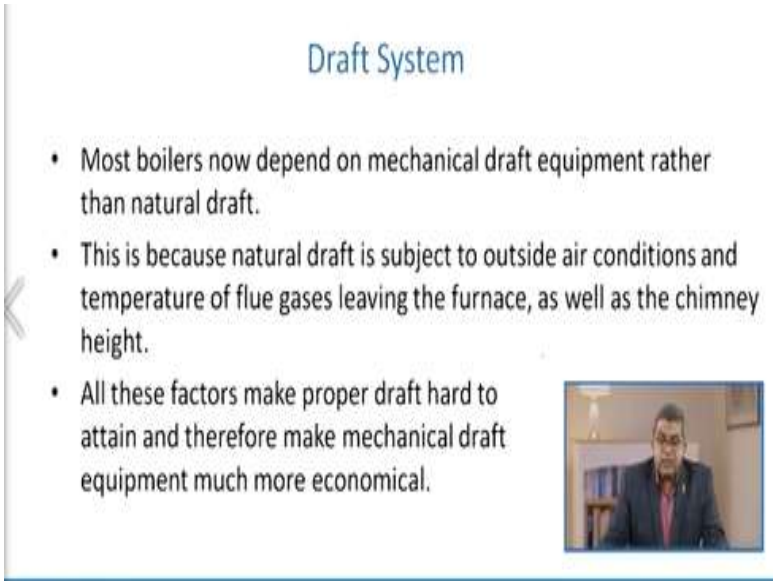

Now let us talk about the draft system. Now, most boilers depend on mechanical draft equipment rather than the natural draft. So, that easy and free movement of this draft can be possible. This is one of the reasons in most scientific ways because the natural draft is subjected to the outside air conditions, temperature of the flue gases leaving the furnace and the chimney height.

So, the chimney height temperature and, apart from this, the composition of fuel gases. All these are contributing factors to the natural draft. All these factors make the proper draft extremely hard to attain and make mechanical draft equipment much more economical.

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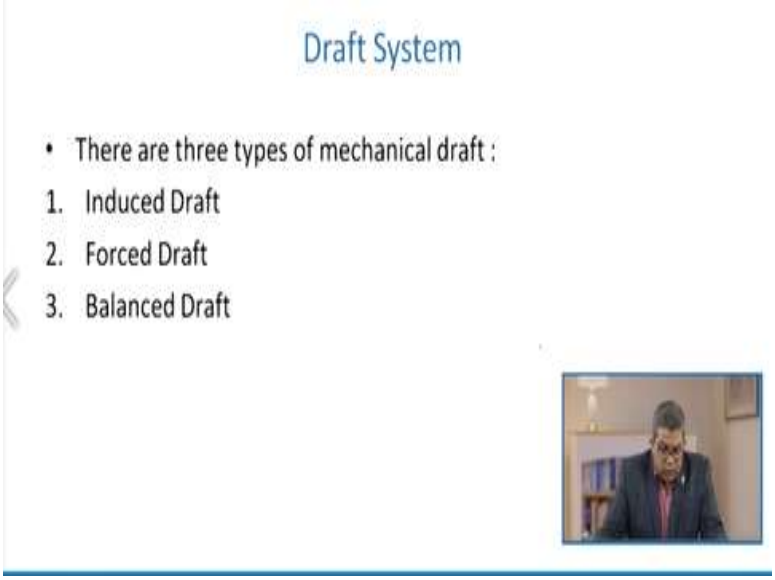

Usually, we have three different types of the mechanical draft, one is the induced drop, the second is the forced draft, and the third is the balanced draft.

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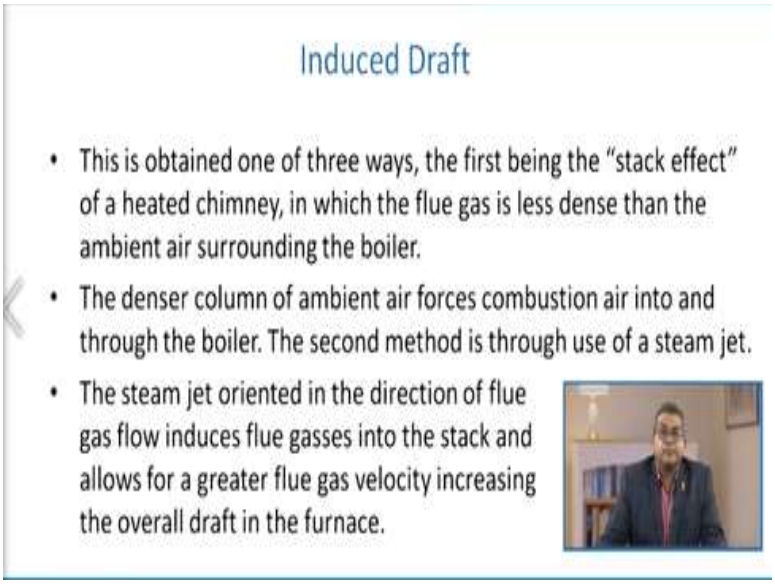

Now induced draft, this is obtained one of the three ways, and the first is the stake effect or a heated chimney in which the flue gas is less dense. Because there is less dense than the ambient air surrounding the boiler at a higher temperature. Now the denser column of ambient air forces the combustion air into and through the boiler. The second method is to use a steam jet etc.

Usually, the steam jets oriented in the direction of the flue gas flow induce the flue gas into the stake and allows for a greater flue gas velocity increasing the overall draft in the furnace.

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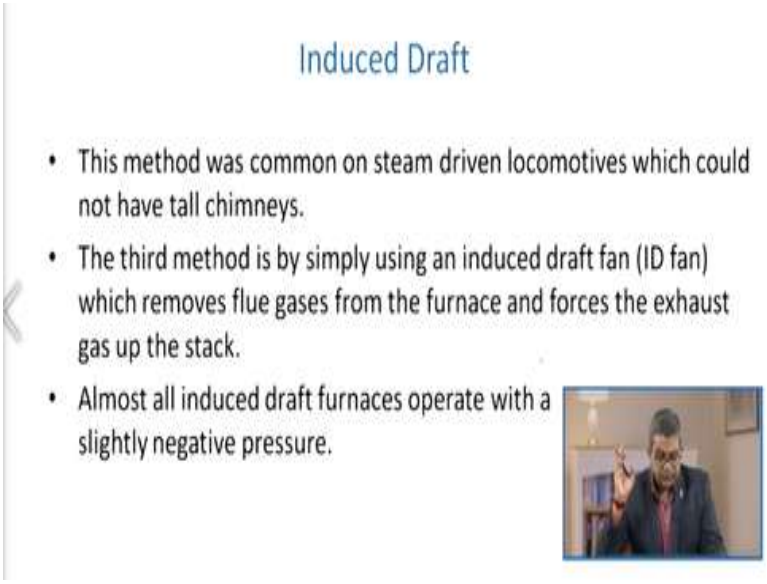

This method was common on steam-driven locomotives that could not have a tall chimney. Because the tall chimney they cannot afford during the movement may create a problem. The third method is by simply using an induced draft fan and an ID fan, which removes the flue gases from the furnace and forces the exhaust gas up to the stack. Almost all induced draft furnaces operate with slightly negative pressure.

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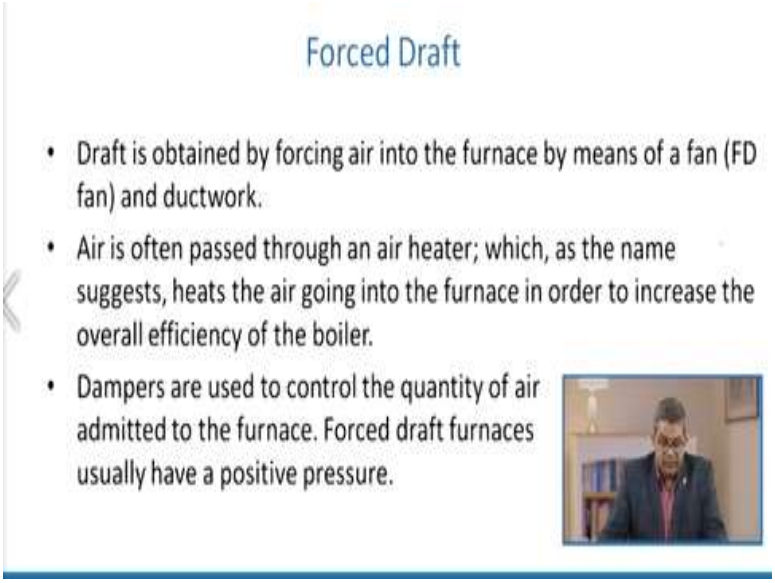

Let us talk about the forced draft. Now, this draft is obtained by forcing air into the furnace using a forced draft fan and ductwork. Air is often passed through an air heater with a name it suggests that heats the air going to the furnace to increase the boiler's overall efficiency. Sometimes,

dampers control the quantity of air admitted to the furnace, and forced draft furnaces usually have a positive pressure.

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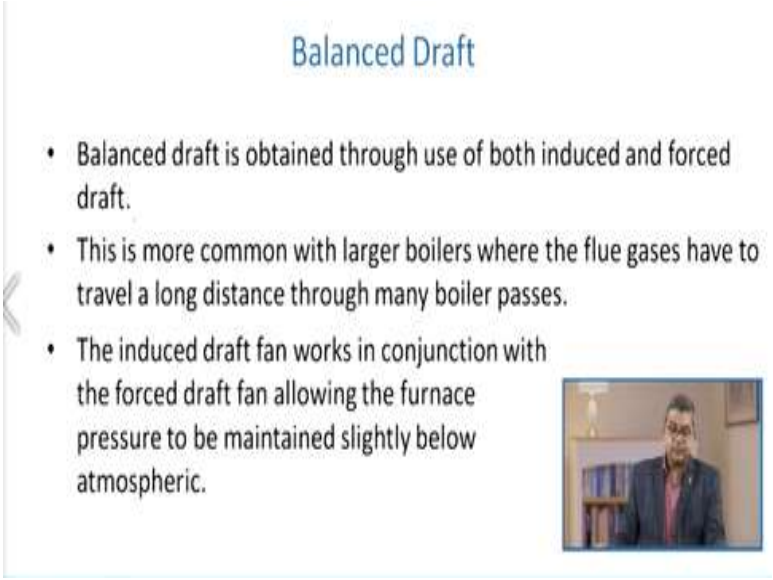

Next is a balanced draft; the balanced draft is obtained through both induced and forced drafts. This is more common with the larger boilers where the flue gas has to travel a long distance through many boiler passes. The induced draft fan usually works in conjunction with the forced draft fan and the furnace pressure to maintain a slightly below atmosphere. In this particular chapter or lecture, we discussed the various parts of the steam generation unit.

Especially the fuel then stacks then steam burners etc. And we discussed various integral parts attributing to the proper steam generation unit segments.

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References

- Chapter 1-Steam, The Babcock Wilcox company
- Buecker, Brad - Fundamentals of steam generation chemistry-PennWell Corp (2000)
- S. C. Stultz, J. B. Kitto - Steam_ Its Generation and Use (41st Edition)-Babcock & Wilcox Company (2005)
- Robert H. Perry, Don W. Green - Perry's Chemical Engineers' Handbook-McGraw-Hill Professional (1997)

For your convenience, we have enlisted four references. If you wish to have more studies or more knowledge, you can go through all these references. Thank you very much.