Chemical Process Utilities
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Lecture - 21
Industrial Boiler Types

Welcome to the industrial boiler types under the aegis of chemical process utilities. Before we go into the detail of this particular aspect, let us look at what we had discussed in the previous lecture. Previously, we discussed the basic qualification of boilers; we discussed the different types of boiler classification: fire tube boiler, water tube boiler, etc.

So, different types of boilers may be based on the pressure; it may be based on the fuel and the other aspects in question.

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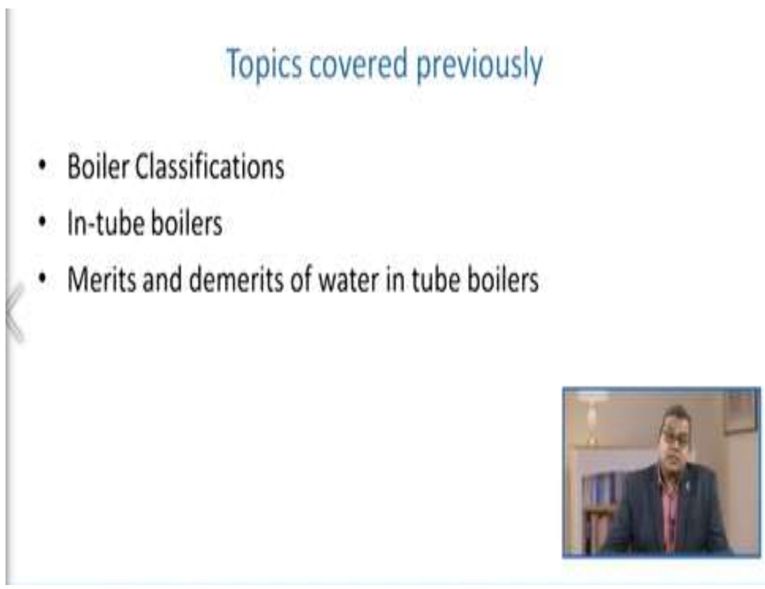

We have discussed the tubing system of boilers. We discussed the merit and demerit of the water in tube-type boilers. In this particular lecture, we will discuss the concept of stoker fire boilers.

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Topics to be covered

- Stoker Fired Boiler
- Pulverized Fuel boiler
- Fluidized bed combustion boiler
- High Pressure boilers

We will discuss the pulverized fuel boiler; pulverization is a very common phenomenon in chemical engineering we will discuss it. Then we will discuss the fluidized bed combustion boilers. Again, to maximize the boiler's efficiency, these are the different types of boilers; we will discuss the concept of a high-pressure boiler. Now see when we talk about the boiler.

So, the first question usually comes to our mind is whether this particular boiler meets our requirements regarding the energy, the esteem, and the other aspect in which they are designed. The second aspect that usually comes to our mind is the boiler's efficiency concerning the energy because everywhere you require the fuel. And obviously, we will require the proper efficiency of the boiler and maximization of the fuel economics.

And the third aspect usually comes to our mind is attributed to the environmental aspect. What is the composition of the flue gases? How many flue gases are there? And obviously, this all depends on the choice of fuel, the boiler design, and the boiler used in the question. So, based on this particular aspect, different types of boilers and inner configurations of the boiler or anatomy have been devised.

Now stoker filed boiler is again one of that particular anatomy of the boiler. So, these stockers are usually classified according to the method of feeding the fuel to the furnace and by the type of the grid. Now usually, we have different choices of fuel. One of the best fuel choices is coal and how we are feeding this particular coal or fuel to the boiler based on this stoker type of thing.

So, when we talk about this stock, the stoker fired the boiler. There are two types of classification.

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One is the chain-grate or traveling-grate stoker, and the second is the spreader stoker.

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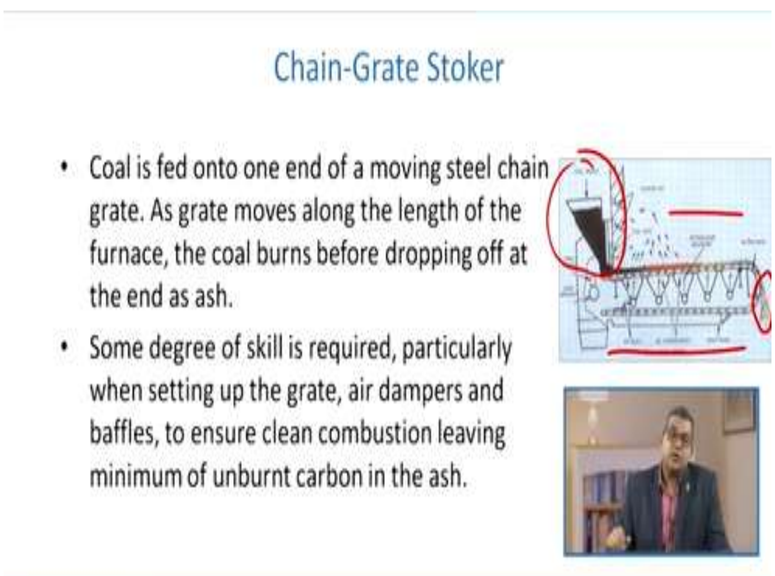

So, let us discuss the chain-grate stoker type of boiler. Now here you see that as per this particular diagram, we are feeding the coal at one end, and there is a steel chain grate here you see that is steel chain grate. Now, as grates move along the length of the furnace, the coal burns before dropping off at the end as ash. Now see, it is a simple combustion process. For combustion, what do you require?

That is a source of carbon that supplies by coal. Second is the adequate supply of oxygen, and, in the boiler system, we are using the air as a source of supply. So, this particular combustion process releases the energy, and if it is complete combustion or partial combustion, some sort of ash. Now here, if you see certain air seals, air compartments, etc.

All these things are mentioned here to maximize the combustion process because we had already talked about the energy efficiency aspect. So, if there is incomplete combustion, your boiler efficiency will be on the lower side. Now here you see that some skill is required, particularly when setting up the grid, air dampers, and baffle.

Because usually, baffles are used to ensure; clean combustion leaving a minimum of unburnt carbon in the ash. Otherwise, it may pose the environmental problem and create the non-economical operation aspect of that particular boiler.

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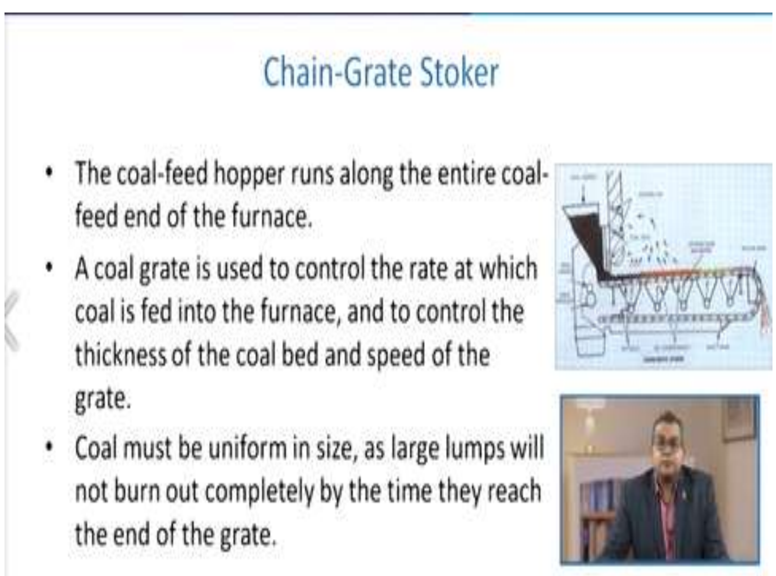

Now the coal feed hopper usually, this is the coal feed hopper is runs along with the entire coal feed, and you see over here to the end of the furnace. A coal grate is used to control the rate at which the coal is fed into the furnace. So, if the rate is on the higher side, you may experience certain amounts of coal being unburned. Now to control the thickness of the coal bed and the grate's speed, this particular grate is being used again.

Because the size of the bed is on the higher side, there may be a chance of the formation of a stagnant zone, and these stagnant zones may create the concept of unburnt coal. Apart from this, another requirement is that this coal must be uniform in size, the large lump may create the problem of unburnt carbon, and sometimes it may be very difficult to burn them completely till they reach the end of the grid. So, these are the complexities.

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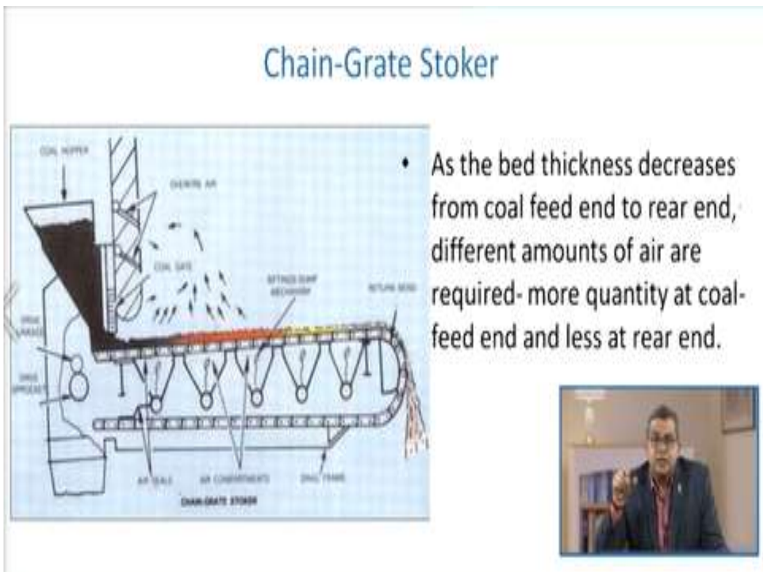

Now, as the bed thickness decreases from coal feed to the rear end, a different amount of air is required, with more coal feed and less at the rear end. When we talk about the combustion process, we are feeding air. Now air, again sometimes repeat sometimes it costs. So, that is why the optimized supply of air is again quite essential, and that is why whenever there is depletion in the amount of coal, you can alter the supply of air to the boiler system.

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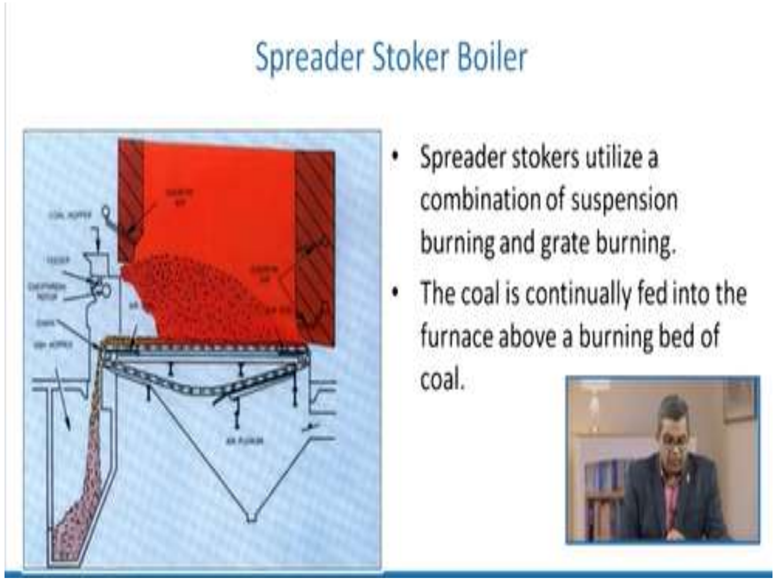

Now let us talk about the spreader stoker boiler. Now the spreader stokers utilize the combination of suspension burning and grate burning. Now usually, suspension burning offers a higher surface area, and in that case, the combustion efficiency is on the higher side. So, usually, the coal is continually fed into the furnace above the burning bed you can see over here.

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And the coal fines or the fine particle coal are burnt in suspension. So, the larger particles fall to the grate when burnt in a thin, fast-burning cool bed. Now, this firing method provides good flexibility to meet load fluctuation, now since you see that ignition is almost instantaneous when the firing rate is increased. Therefore, the spreader stoker is favored over another type of stoker in many industrial applications.

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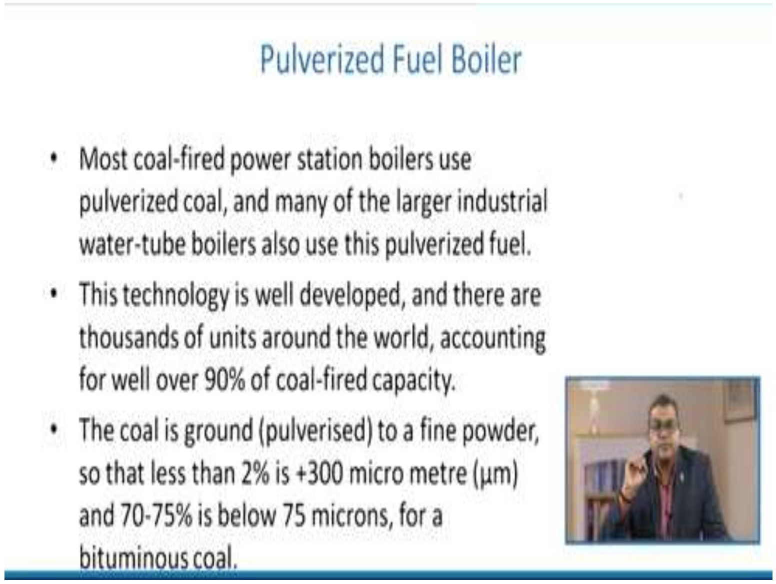

Now let us talk about the pulverized fuel boiler. Now, most coal-fired power station boilers use pulverized coal and many of the larger industrial water-tube boilers also use this pulverized fuel. Nowadays, this particular technology is well established or well developed, and there are thousands of units around the world accounting for well over, you can say, 90% of coal-fired capacity.

So, usually, what is the concept? The concept is that the coal is ground or pulverized to a very fine powder. So, less than 2% is plus 300 micrometer, and almost 70 to 75% is below 75 microns for bituminous cold.

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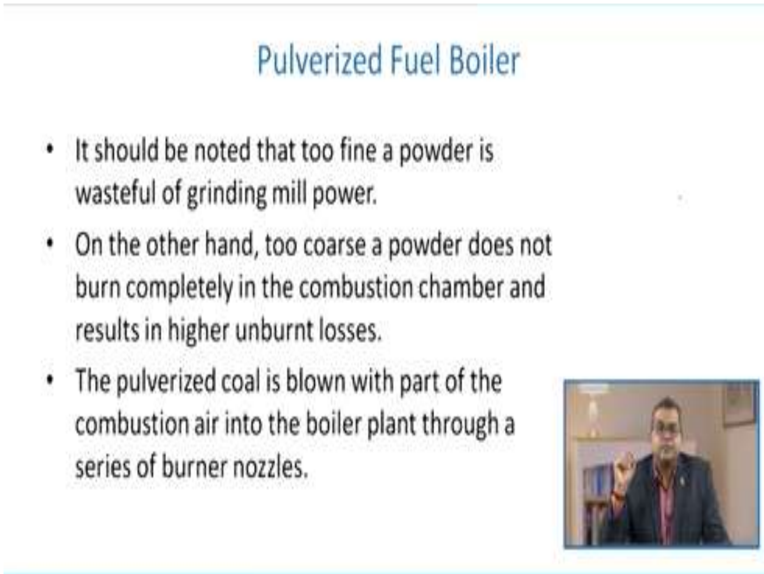

It should be noted that a two fine powder is again wasteful in grinding mill power. Now you usually need to incorporate more and more power to make them fine powder, and sometimes it may become charred over time. On the other hand, if you have too coarse powder, it does not burn completely in the combustion chamber and results in higher unburned losses.

So, the pulverized coal is blown with part of the combustion air into the boiler plant through burner nozzles.

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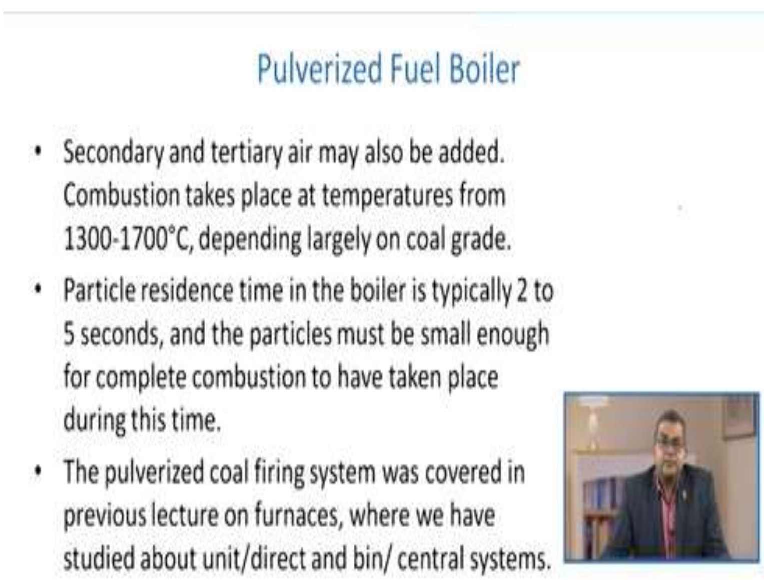

Now sometimes, you may need to incorporate the secondary and tertiary air. Now, this air may be added to the combustion process. Now combustion usually takes place at a temperature from say

1300 to 1700 degrees Celsius depending upon the quality of the coal, or you can say the grading of the coal. You may see that the particle residence time in the boiler is typically 2 to 5 seconds. Again it is an art to maintain this residence time.

So that the; combustion efficiency may be enhanced. So, the particle must be smaller enough for complete combustion to occur during that particular time. The pulverized coal firing system was covered in the previous lecture, as you noticed on the furnace where we studied the unit direct bin central type of a system.

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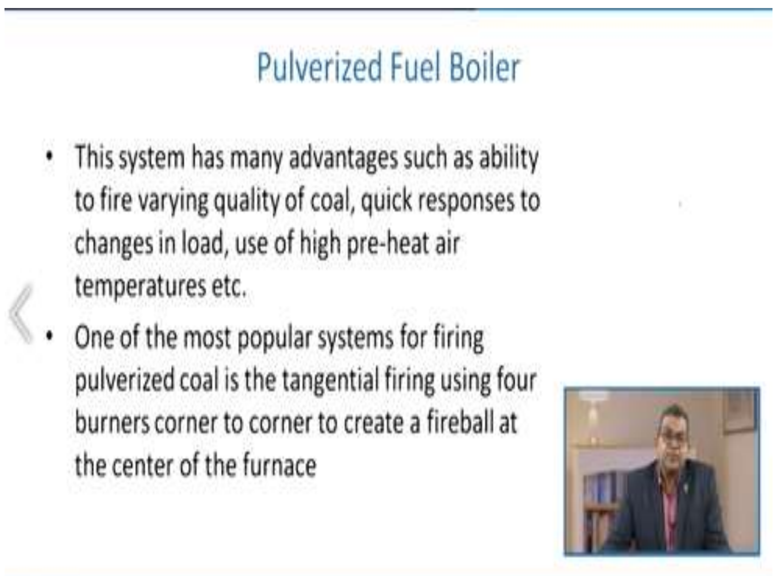

Now, this system has many advantages likeability for fire, varying coal quality, quick responses to changes in load; you may use the high preheat air temperature, etc. One of the most popular systems of firing pulverized coal is the tangential firing using a four-burner corner to corner to create a firewall at the center of the furnace. So that you may experience the; enhanced temperature.

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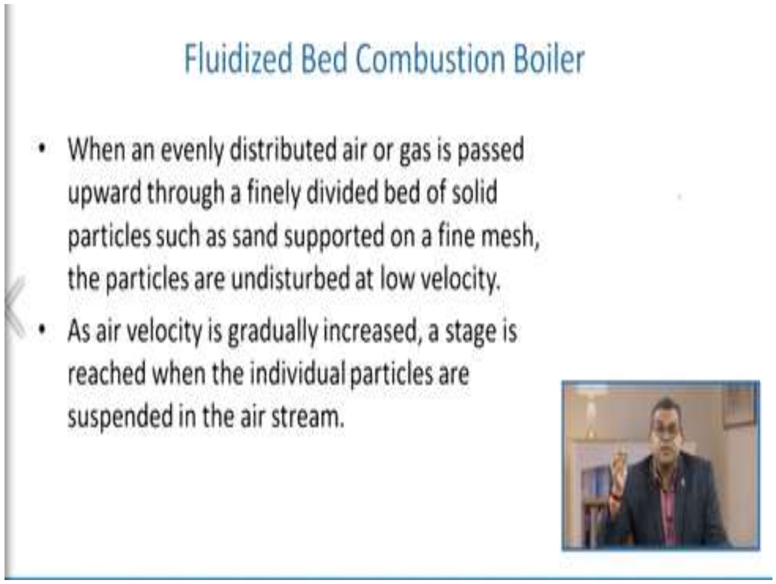

Now let us talk about the fluidized bed combustion boiler. When an evenly distributed air or gas is passed upward through a finely divided bed of solid particles such as sand supported on fine mesh, the particles are undisturbed at a low velocity. Now, as you gradually increase the air velocity, a stage is reached when individual particles are suspended in the air stream so that the; uniform distribution of air may occur.

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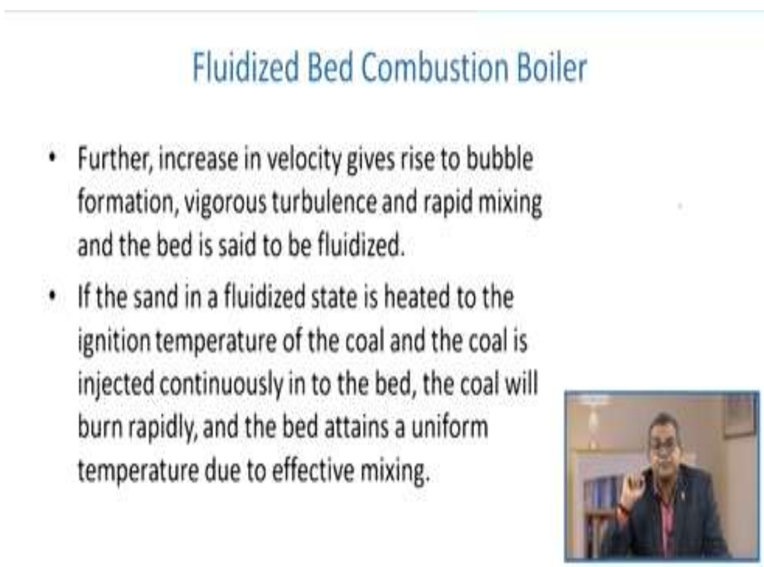

Now, if you further increase in velocity, this gives rise to bubble formation, vigorous turbulence, and rapid mixing, and the bed is said to be fluidized. This is the usual phenomenon of fluidization. Now, if the sand in a fluidized state is heated to the ignition temperature of the coal and coal is injected continuously into the bed, the coal will burn rapidly, and the bed attains a uniform temperature due to effective mixing.

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Now in this particular case, the proper air distribution is extremely important. This is to maintain uniform fluidization across the bed. Now ash is disposed of by dry and wet ash disposal systems. Fluidized bed combustion has significant advantages over conventional firing system and usually offer multiple benefits like fuel flexibility, reduced emission of harmful pollutants such as SOx, NOx, complete compact boiler design, and higher combustion efficiency.

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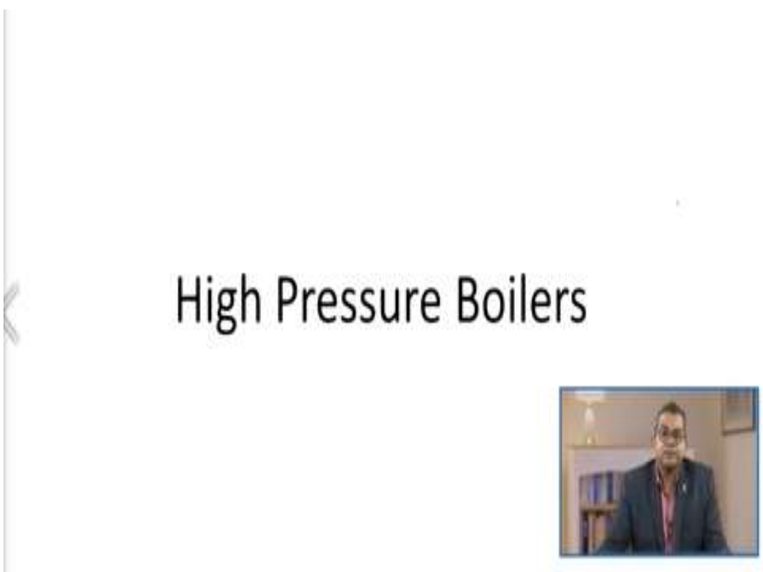

Now let us talk about high-pressure boilers. High-pressure boilers are again very useful in various industrial operations. You may sometimes require variation in the pressure may be as per the choice of your process, then these are very good candidates.

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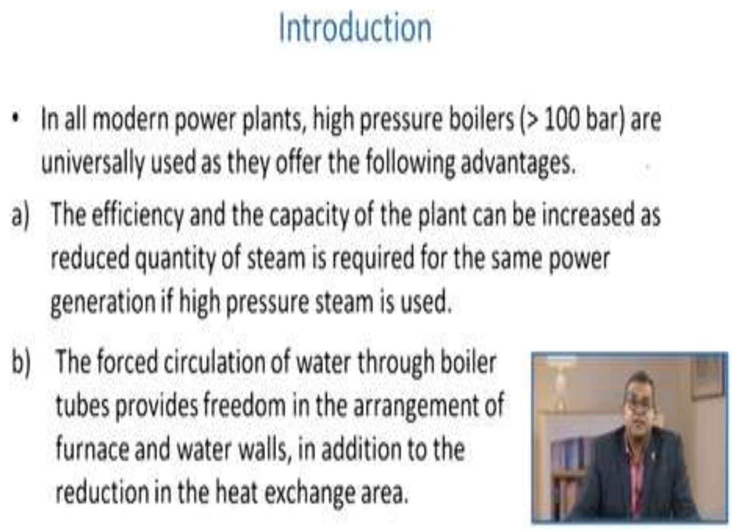

So, in all modern power plants, high-pressure boilers, usually greater than 100 bar, are universally used as they offer different advantages. One of the advantages is that the plant's efficiency and capacity can be increased. It can be reduced as the quantity of as per the choice as per the quantity of the steam required for the system. So, if you require the same power generation if high pressure is stream is used.

Then you can enhance or reduce the different parameters as per the requirement. Now the forced circulation of water through boiler tubes provides freedom in the arrangement of furnace and water walls, in addition to the reduction in the heat exchange area.

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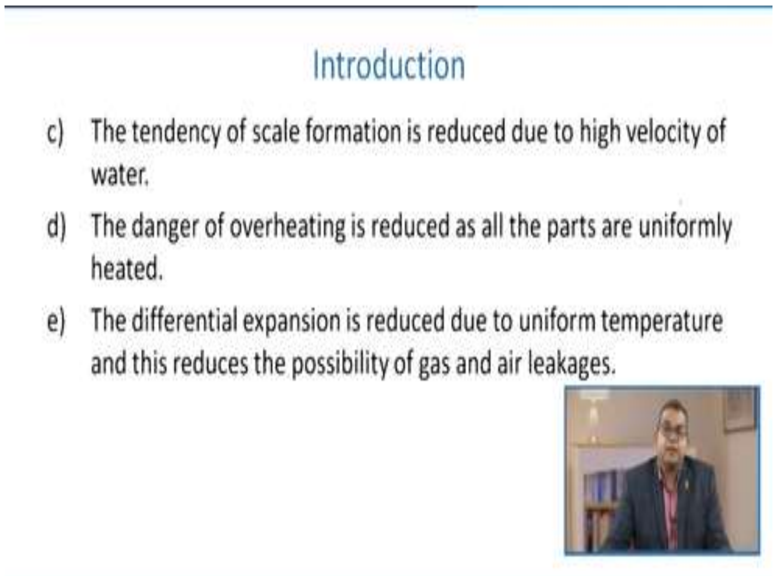

Now the tendency of scale formation is reduced due to the high velocity of the water. We use high velocity, so the deposition rate is substantially lower. The danger of overheating is also reduced as the parts are uniformly heated. So, overheating bending of tubes shell, etc., these kinds of things can be avoided. The differential expansion is reduced due to uniform temperature, reducing the possibility of gas and air leakage.

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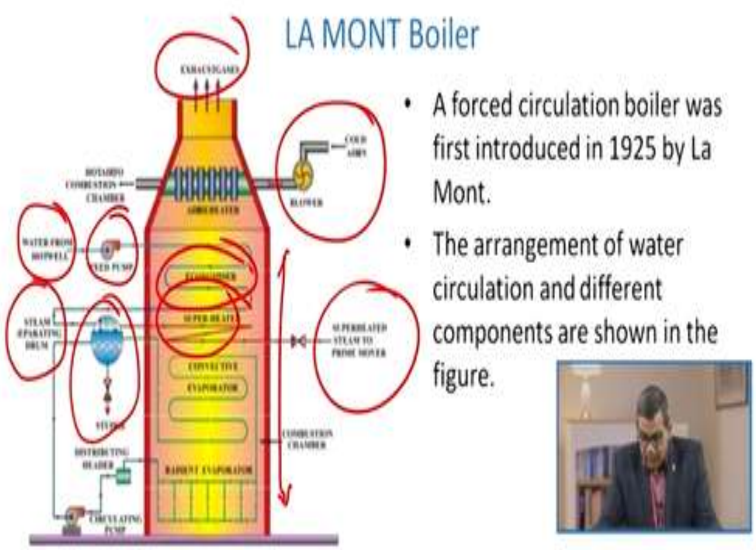

Now let us talk about the La Mont boiler in this category. Now, this is the typical figure of the La Mont boiler. A couple of things are very common in every boiler that there must be a route for exhaust gases like here we are having. There must be a combustion chamber like here we are having; there must be some steam releasing system or steam separators, you must have some water feed pump, etc.

If you are recirculating the things or steam you are super heating the steams, there must be a sludge removal device. To maximize efficiency, you must have an economizer in place and a super heater. So, all these things are there in every type of boiler, so usually, in the La Mont boiler, a forced circulation boiler is termed a force circulation boiler, and it was introduced in 1925 by La Mont.

With the arrangement of water circulation and the different components we have already enlisted, you can see here there is a radiant evaporator, and you see that the water is passing through. So, it is being preheated and giving you the superheated steam in this way.

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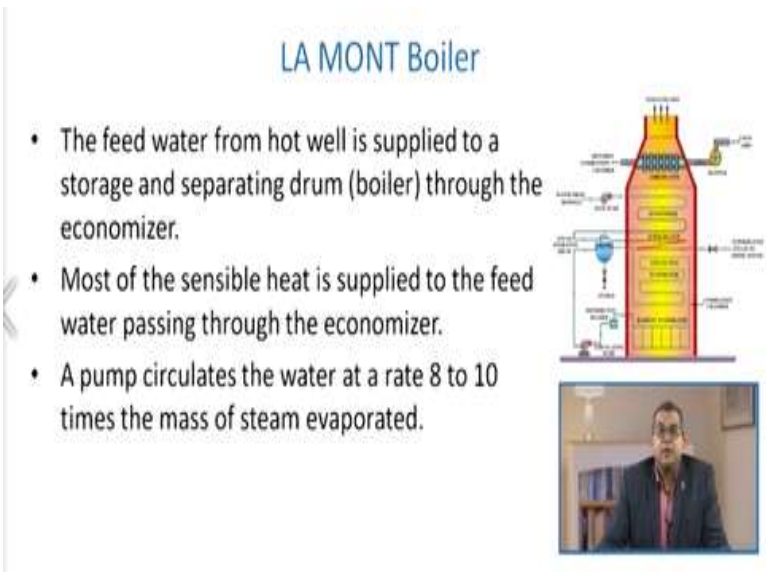

Now, if you see that the hot well's feed water is supplied to storage and separating drum that is a boiler through the economizer here, you see. And after the economizer, things go to the atmosphere or the air treatment plant. Now, most sensible heat is supplied to the feedwater passing through the economizer. Usually, a pump circulates the water at a rate of 8 to 10 times the mass of the steam evaporator. That is the theoretical calculation.

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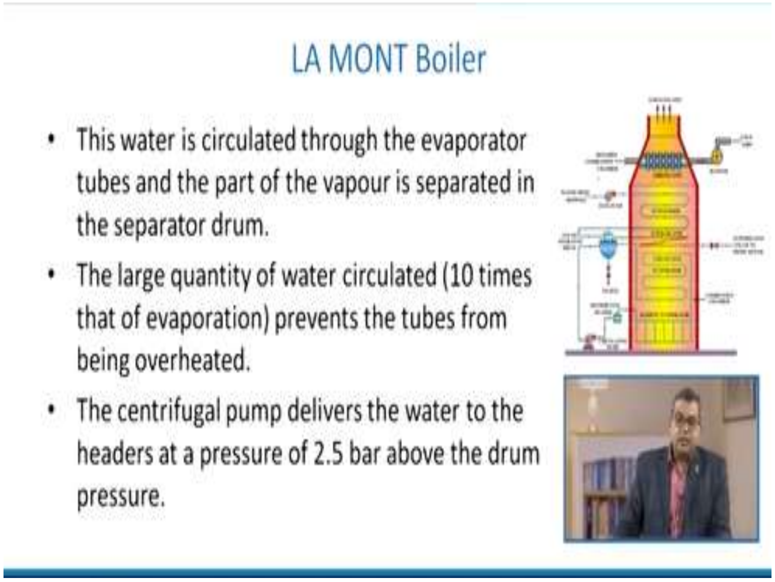

Now, this water is circulated through the evaporator tubes. Here you see that these are the evaporator tubes, and the part of the vapor is separated in the separation dump. The large quantity of water circulated almost ten times that of evaporation it prevents the tube from overheating. So, this is a plus point because the bending of tubes or deformation of the tubes can be easily avoided.

Now usually, the centrifugal pump delivers the water to the header at a pressure of 2.5 bar above the drum pressure, and that is again a very plus point.

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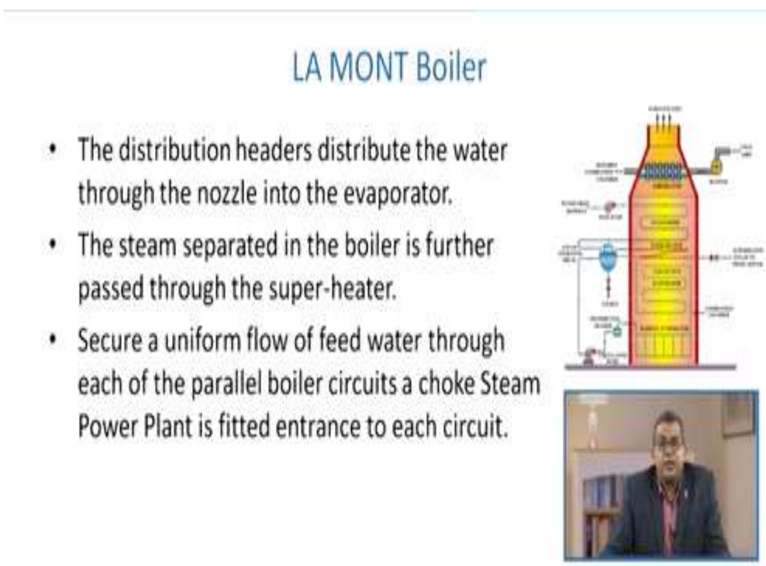

So, the distribution header distributes the water through the nozzle into the evaporator. So, the steam separated in the boiler is further passed through the superheater. Here you see that this is the superheater. Now secure a uniform flow of feed water through each parallel boiler circuit. A choke steam power plant is fitted at the entrance of each circuit.

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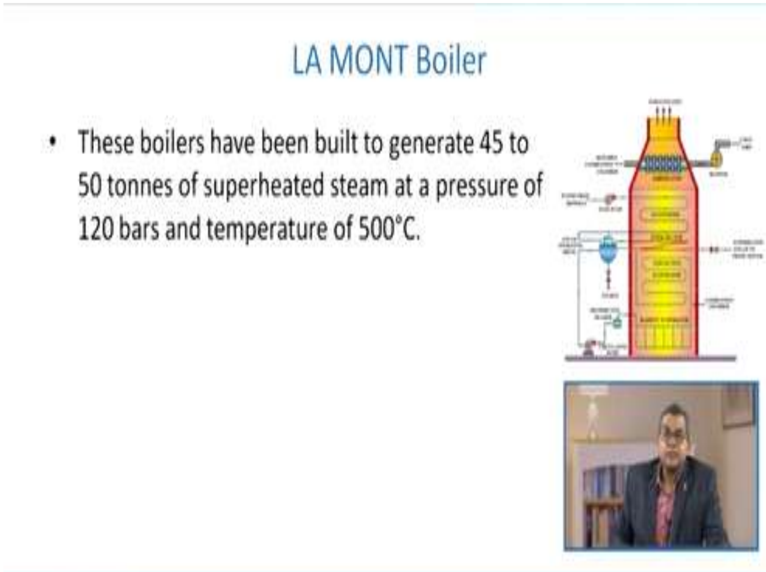

These boilers have been built to generate 45 to 50 tonnes of superheated steam at a pressure of 120 bars. The temperature usually is around 500 degrees Celsius for different industrial uses.

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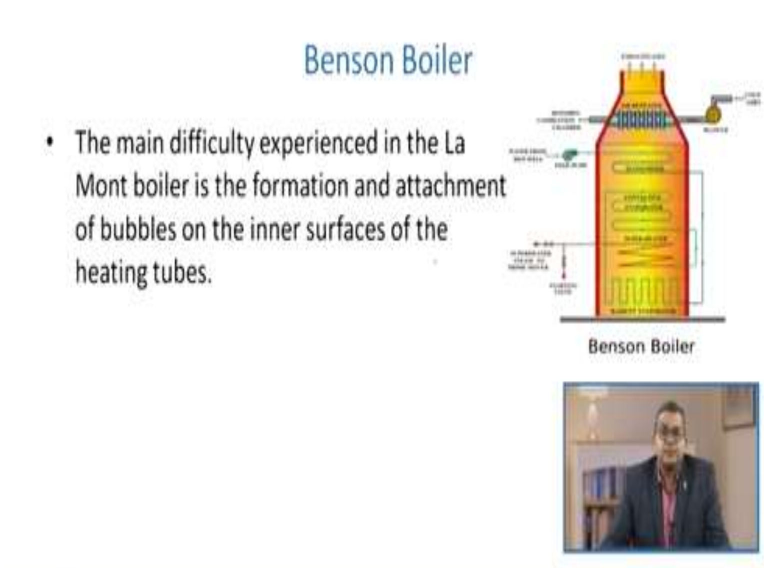

Now let us talk about the Benson boiler. So, now Benson boiler is evolved somewhat later than the La Mont boiler because the main difficulty experienced in the La Mont boiler is the formation and attachment of bubbles on the inner surface of the heating tube. So this may cause corrosion and may cause some foam formation.

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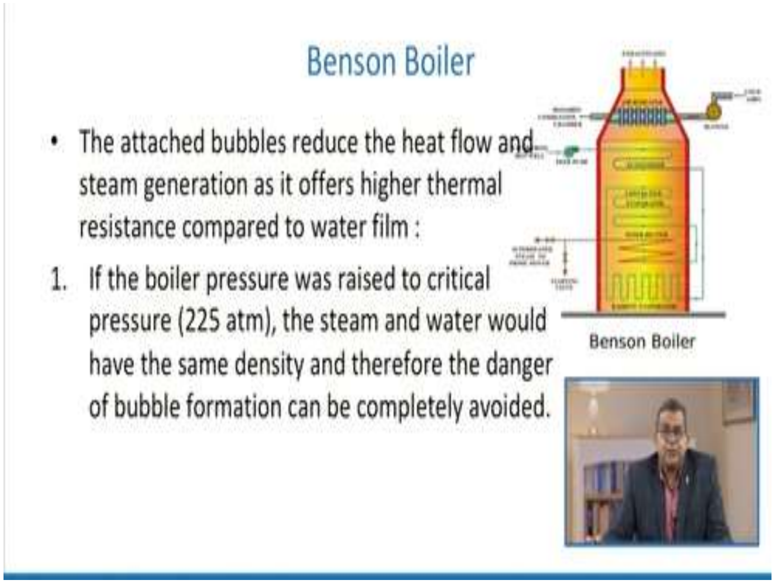

So, that is why the Benson boiler evolved; now, the attached bubbles reduce the heat flow in steam generation as they offer higher thermal resistance than a water film. So, if the boiler pressure is supposed to raise to a critical pressure, which is 225 atmosphere, the steam and water usually have the same density. Therefore, you can easily or completely avoid the danger of bubble formation in a Benson-type boiler.

So, it was a very small phenomenon through which you can utilize and maximize things. So, from the La Mont boiler to the Benson boiler, the system evolves.

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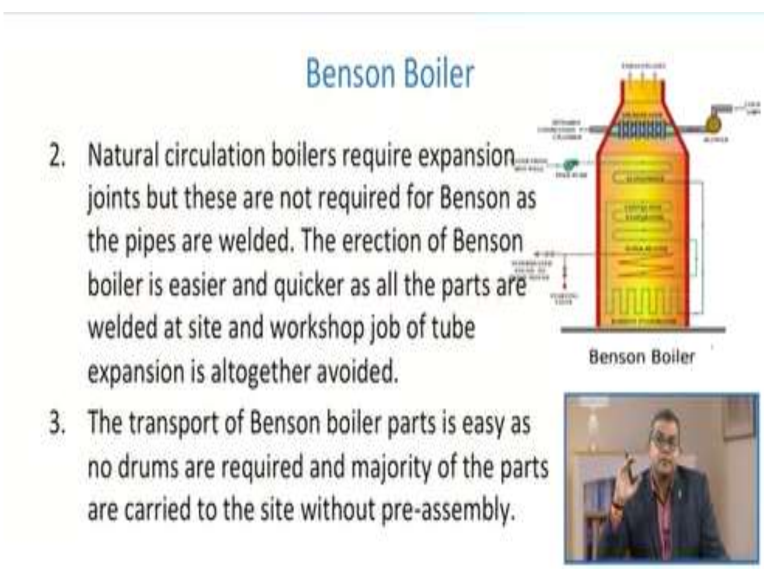

The natural circulation boilers usually require expansion joints, but these are not required in the Benson boiler. Now the thing is that if you have expansion joints, the chances of wear and tear may be more prominent. So, the erection of the Benson boiler is usually easier. It is much quicker than the previous one. Now because the reason is that all the parts are welded at the site, and the workshop job of tube expansion is altogether avoided.

So, these two added benefits offer, and they pose a good candidacy for Benson boiler over La Mont boiler. Transportation is again a very crucial aspect of the boiler system. The Benson boiler part is easy because no drums are required, and most of the parts are carried to the site without pre-assembly.

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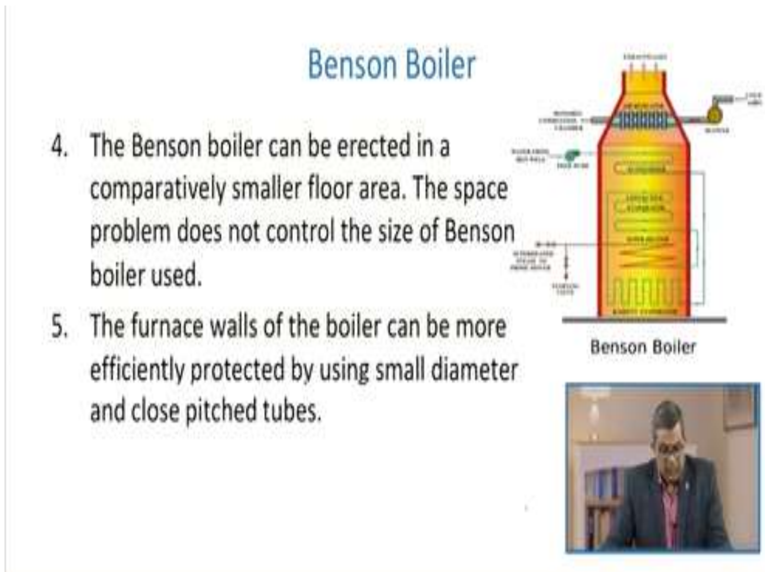

This Benson boiler can now be erected in a comparatively small floor area. The space problem does not control the size of the Benson boiler. Whatever Benson boiler you are using does not pose any kind of a restriction. The furnace walls of the boiler can be more efficiently protected by using the small diameter and closed pitch tubes. So, you can say the protection of this boiler concerning the safety is again can be secured.

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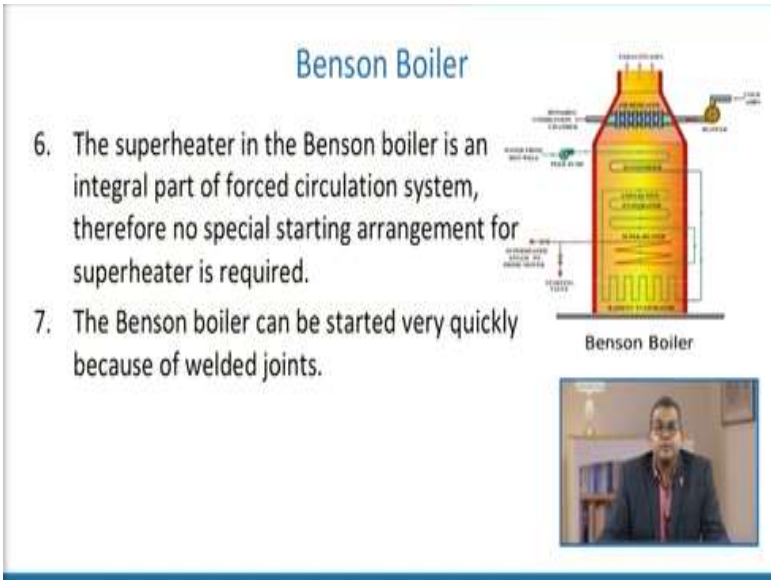

The superheater, the superheater in the Benson boiler, is usually an integral part of the forced circulation system. So, therefore no special starting arrangement for the superheater is required. Now superheaters are again sometimes is a very, you can say useful attachment to the boiler to maximize the efficiency and because sometimes see if you are extracting the steam from the boiler and taking it externally to a superheater.

Then you require some additional energy source as well, as there maybe you may experience the pressure drop condensation all these things may come club together. So, this offers the in-house arrangement of superheated within the boiler system, which is why it is again a very beneficial aspect. Now again, this Benson boiler can be started very quickly because there is no expansion joint of the welded joint.

So, you may not experience any kind of leakage or other wear and tear problem, and you can start very quickly.

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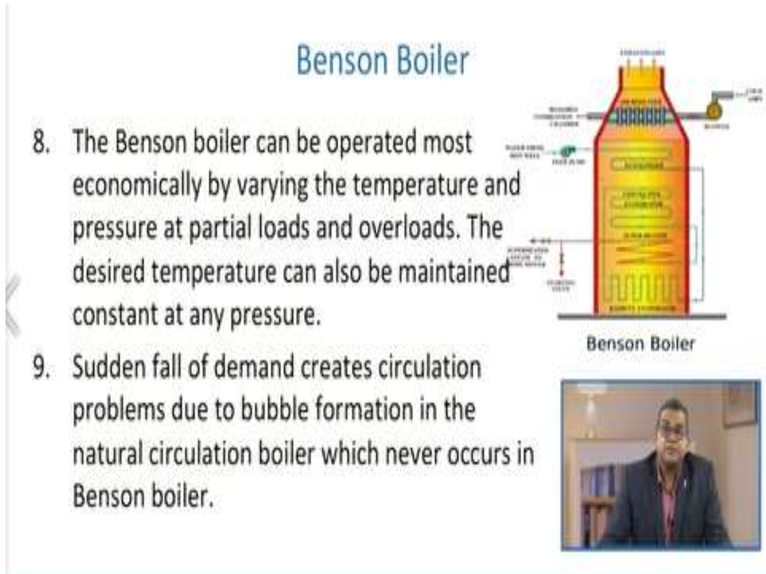

These Benson boilers can operate most economically by varying temperature and pressure at partial loads and overloads. So, the desired temperature can also be maintained constant at any pressure. So, you may see that a lot of flexibility is attached to these boilers. You may vary. You may optimize the situation as per the requirement because of the pressure and temperature you can easily maintain. Apart from this, there is no you can say the expansion joints.

So, all these things you can see are favorable. Sometimes, you may experience that there may be a sudden fall in demand during the process. And this sudden fall in demand creates a circulation problem due to the bubble formation in the natural circulation boiler. This type of phenomenon usually does not exist in the Benson boiler. So, we may say that this particular phenomenon never occurs in the Benson boiler.

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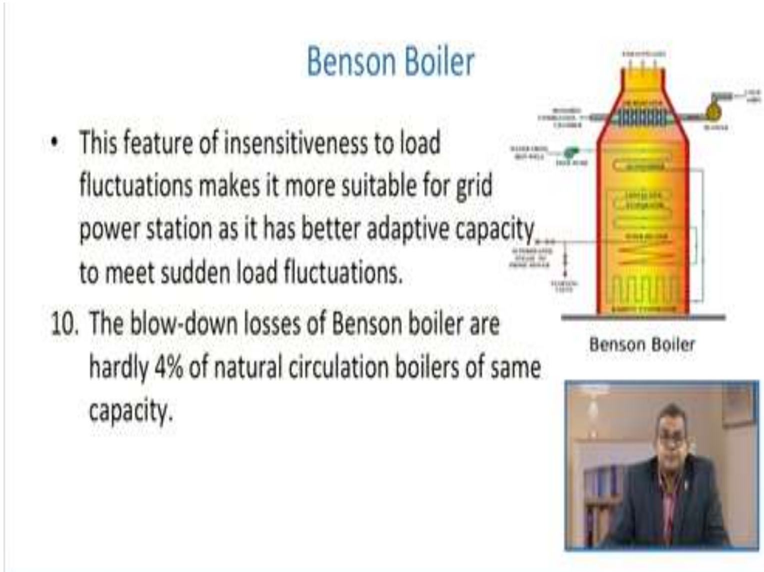

This insensitivity to load fluctuation feature makes it more suitable for grid power stations as it has better adaptive capacities to meet the sudden load fluctuation. And usually, this is a very, you can say, sensitive phenomenon if you have the sudden load fluctuation. And sometimes major accidents may take place because of the overloading of these boilers. So, these types of things are very sensitive.

Again, blow-down losses are very crucial for any kind of boiler operation. So, these blows down losses of Benson boiler are hardly 4% of natural circulation boiler of a similar type of capacity. So, you see that this particular loss is sometimes attributed to the major economic loss in a boiler. So, the boiler operation would be more economical if it is on the lower side.

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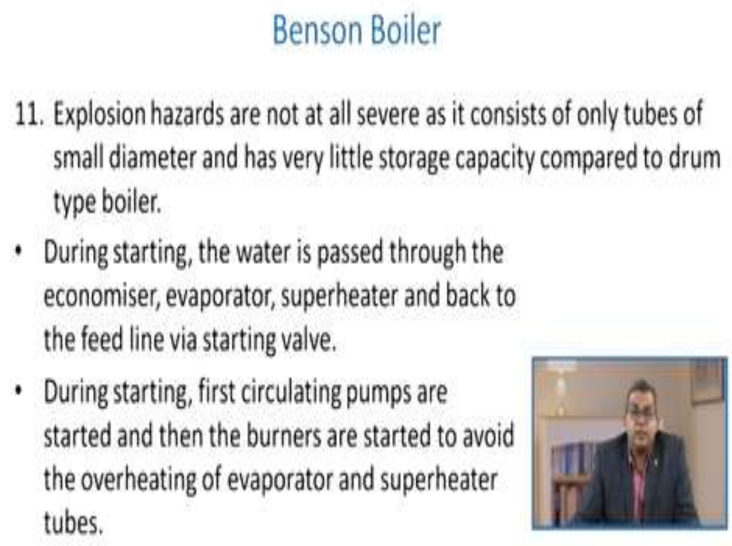

See, boiler safety is a crucial aspect and phenomenon because the basic definition of boilers suggests that it is a pressure vessels. So, when dealing with a pressure vessel, there may be changes, or there may be chances of explosion hazard since it is a pressure vessel. So, the explosion hazard is sometimes made very severe.

And if you go to the literature, there are various boiler explosion explosive accidents, which create economic loss and human fatality. So, if Benson boiler, if you talk about the Benson boiler, the explosion hazards are not all severe as it consists of only tubes of very small diameter and has a very little storage capacity compared to the drum type of a boiler. So, if they have very less storage capacity, the chances of heat capacity would be on the lower side and by this way.

The explosion hazard or consequences of any kind of explosion are minima. Now, the water is usually passed through the economizer, evaporator, super heater, and back to the feed line via starting valve. So, whatever required energy or heat can be extracted and maximized, it can have a maximized heat efficiency, etc. Now while starting, the first circulating pump is started.

And then, the burners are started to avoid any kind of overheating of the evaporator and superheater tubes. So, these evaporators and superheaters are posing very smart phenomena of energy conservation. So, at the last of this particular lecture, you see that we had discussed this stoker type of system. We discussed this system of boiler classification with the two different types of boilers like La Mont boiler and the Benson type boiler.

And you see that the basic objective of these different types of boiler studies is to cater to the need of your requirement.

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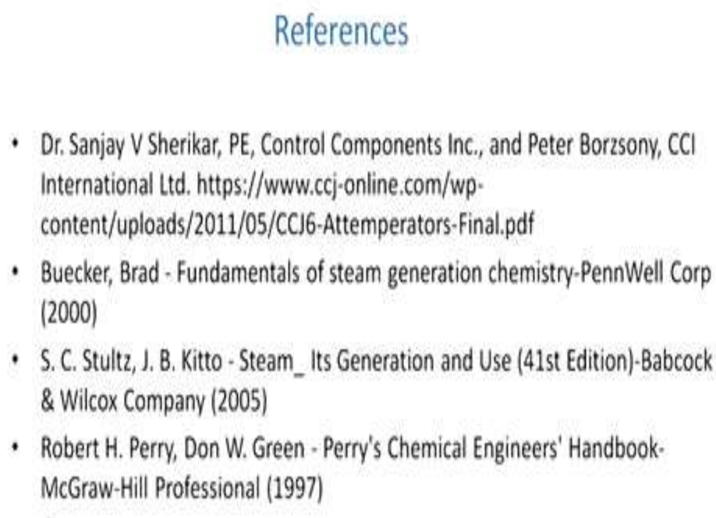

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For convenience, we have enlisted various references. You may go through all these references. Thank you very much.