Chemical Process Utilities
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Lecture - 26
Attemperator and Steam Drum

Welcome to the chapter on the steam drum. Again, the steam drum is an integral part of the steam generation unit or steam distribution system under the aegis of chemical process utilities. Before we go into the detail of the steam drums, just to recap the topics, we covered previously.

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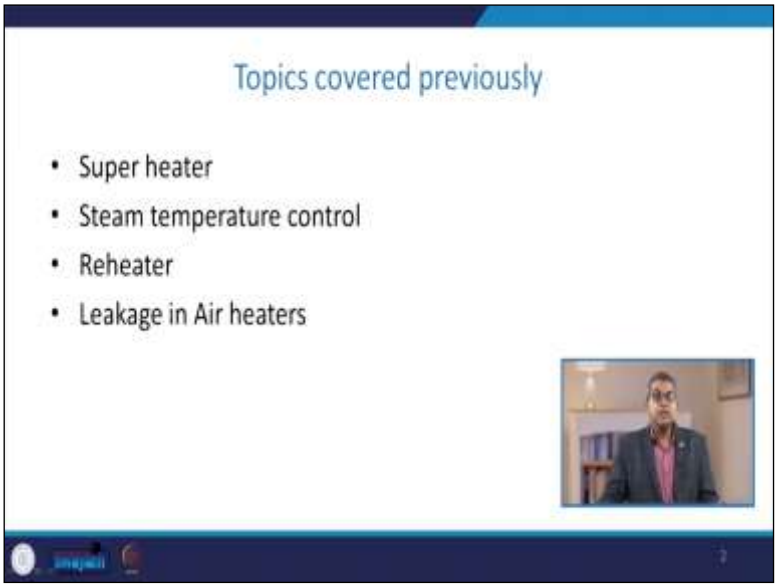

So, previously we covered the topic of superheaters, steam temperature control systems, reheaters, and the concept of leakage in air heaters.

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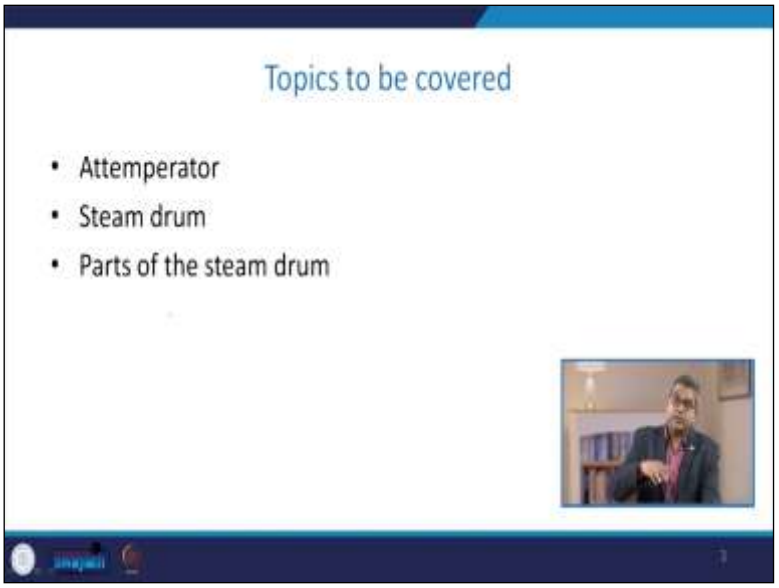

In this particular lecture, we will cover the attemperators, the concept of steam drums, and then we will discuss the various parts of steam drums. Let us start with the attemperators. The boiler attemperators are used to fine-tune or control the steam temperature from a boiler as well as the steam temperature between the boiler stages. Sometimes a different type of boiler stage has been used.

So, they are used to control their steam temperature. What are the desirables in the attemperators?

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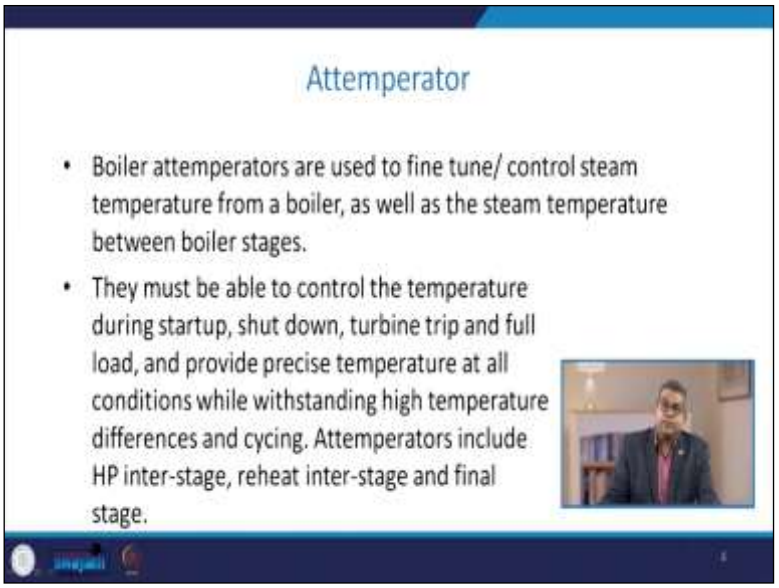

One must be able to control the temperature during startup shut down. Sometimes turbine may get trip, and sometimes turbine runs on a full load and provides the precise temperature at all conditions while withstanding the high-temperature difference and the cycling. These attemperators include the high pressure inter stage reheat inter stage and final stage if you recall that we discussed the various kinds of reheaters in the previous lecture.

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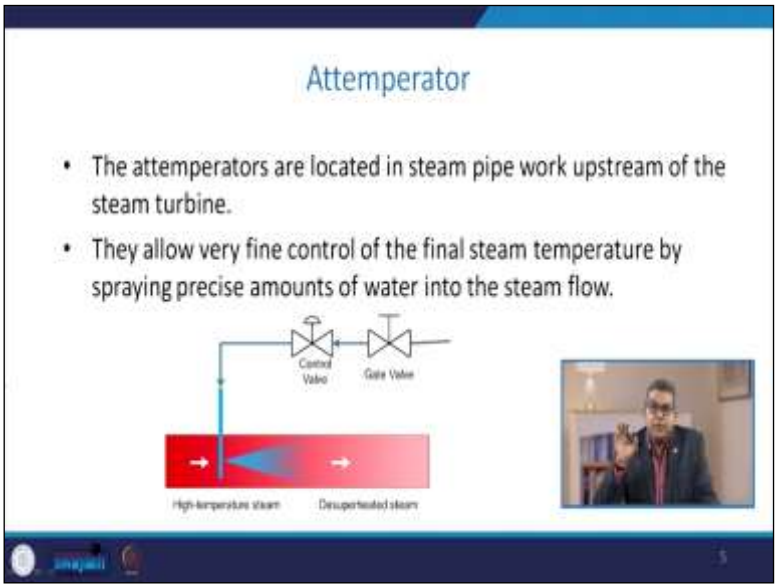

the attemperators are located in steam pipework upstream of the steam turbine. See here, this is the steam pipework, and you have this temperature. So, allow very fine control of final steam temperature by spraying the precise amount of water into the steam flow. So, again this is the usual way to control the steam temperature.

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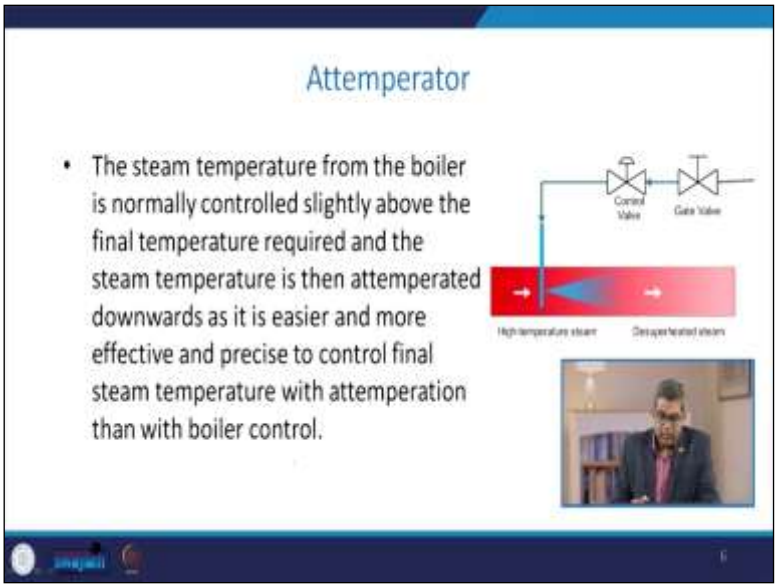

The steam temperature from the boiler is normally controlled slightly above the final temperature required. This is attributed to the various irreversibility associated with the steam piping network. This steam temperature is then attempted downward as it is easier and more effective and precise to control the final temperature with a temperature than with the boiler control. So, in this way, one can maximize the efficiency because sometimes, if you are producing the steam at the desired temperature and pressure at the boiler end.

And if it goes to the point of use, then sometimes you may not have the esteem with the proper temperature or pressure. So, in that case,slightly about the temperature the production of steam at a slightly above temperature always be desirable. But in that case, sometimes you need to go for the precise control of the temperature in that case the attemperators are very useful device.

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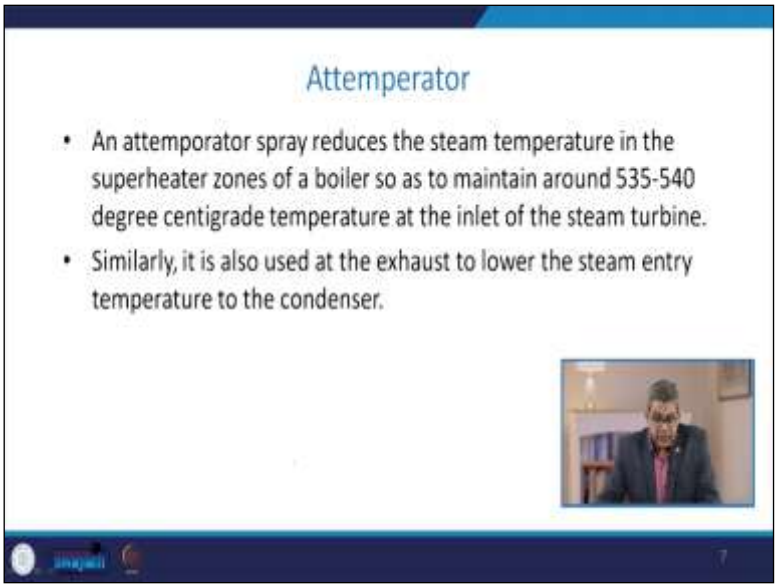

So, a temperature spray reduces the steam temperature in the superheaters zone of a boiler to maintain around, say, 535 to 540 degrees centigrade temperature at the inlet of the steam turbine. Similarly, it is also used as the exhaust to lower the steam temperature in the condenser. So, in this way, you can maximize the efficiency of the condenser.

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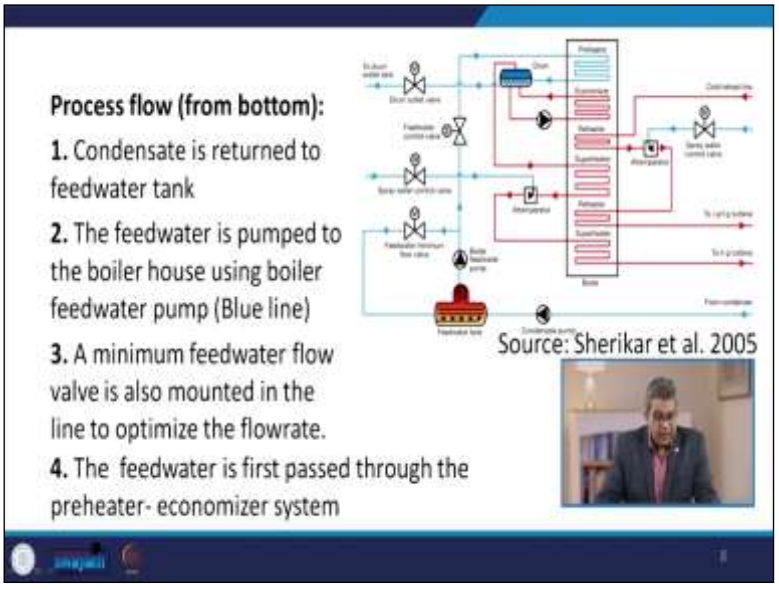

Here you see the process flow diagram. Here you see that the condenser is returned to the feed water tank. Here you can see that this is the feed water tank. This feed water is pumped to the boiler house you see using the boiler feedwater pump this boiler feed water pump. A minimum feedwater flow valve is also mounted in the line to optimize the flow rate which is quite obvious.

And the feed water is first passed through the preheater economizer section here, you see that this goes to either here this is the preheater, and this is the economizer section or system.

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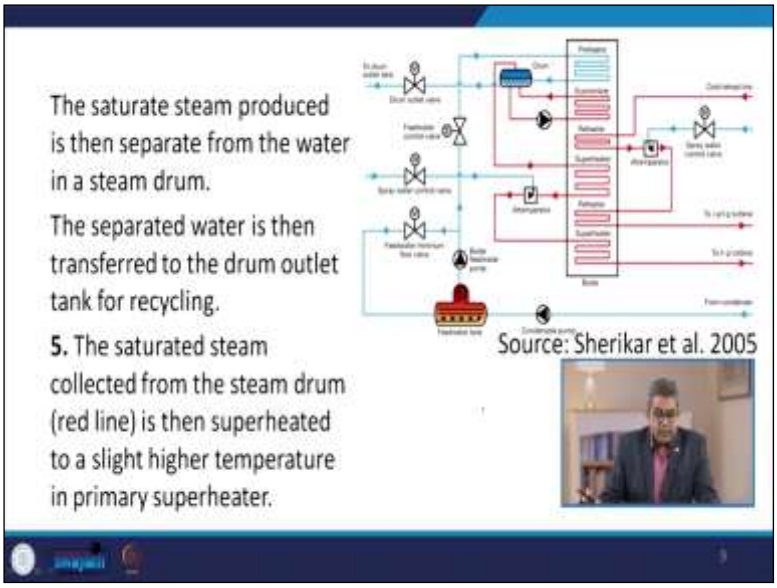

The saturated steam produced is then separated from the water here; this is the drum, separated from the water in the steam drum. As we discussed, this serves as the steam separation unit, and it has the steam chest and the water chest. This is separated water is then transferred to the drum outlet tank for recycling. The saturated steam collected from the drum is then superheated to a slightly higher temperature in a primary superheater.

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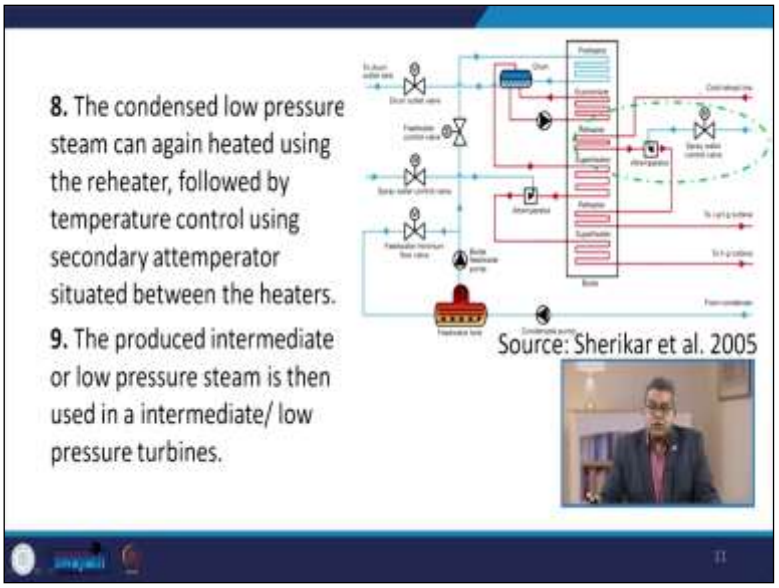

So, you see that there are two superheaters, one and two; the superheated steam temperature is controlled through the attemperator situated between the primary and the secondary superheater using a spray of water. So, you are supplying the spray water through this spray water-controlled wall. The controlled temperature superheated steam is finally superheated up to the desired temperature and pressure for use in a high-pressure turbine.

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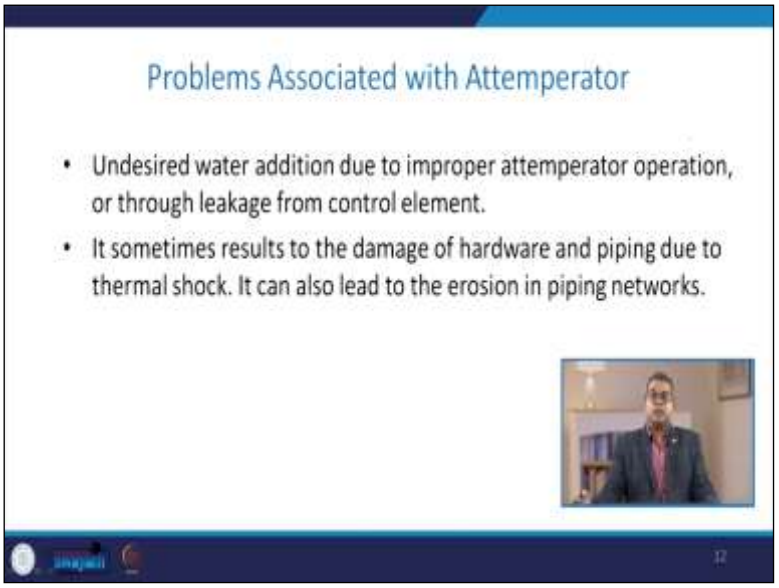

The condensed low-pressure steam can again be heated using the reheater here; this is the reheater followed by the temperature control using the secondary temperature situated between the heaters.

The produced intermediate or low-pressure steam is then used in inter intermediate or low-pressure turbines.

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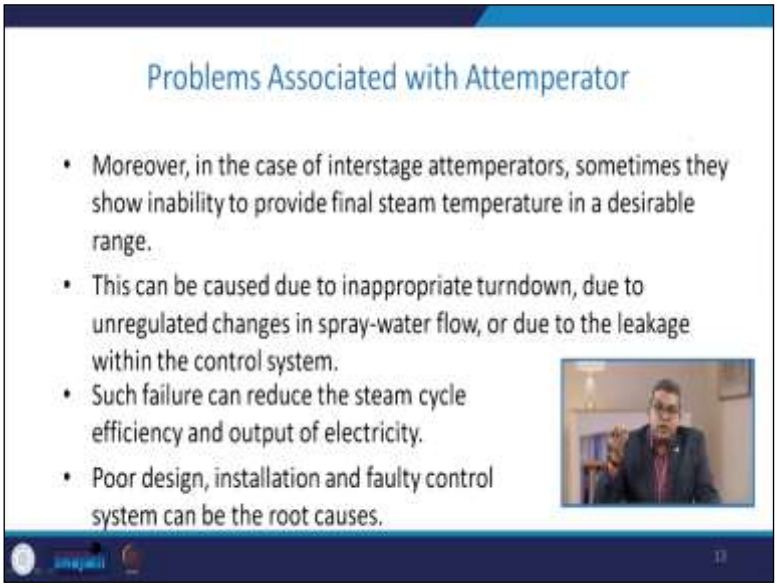

There are several problems associated with the attemperators. One is that undesired water addition due to improper amp temperature operation or through the leakage from the control element. And second is that it sometimes results in damage to hardware and piping due to the thermal shock. It can also lead to erosion in the piping network. Another problem associated with the attemperator is that inter-stage attemperators sometimes fail to provide a final steam temperature in the desirable range.

So, your entire purpose may not be fulfilled; ah, this can be caused due to the inappropriate turn down due to unregulated changes in the spray water flow or due to the leakage within the control system.Sometimes, such failure can reduce the steam cycle efficiency and output of electricity.

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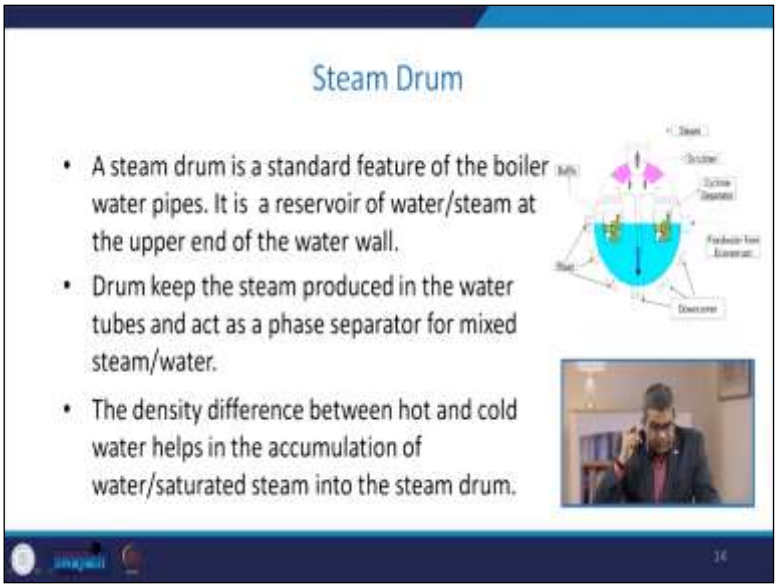

Poor design installation and a faulty control system these can also be the root causes of these problems.

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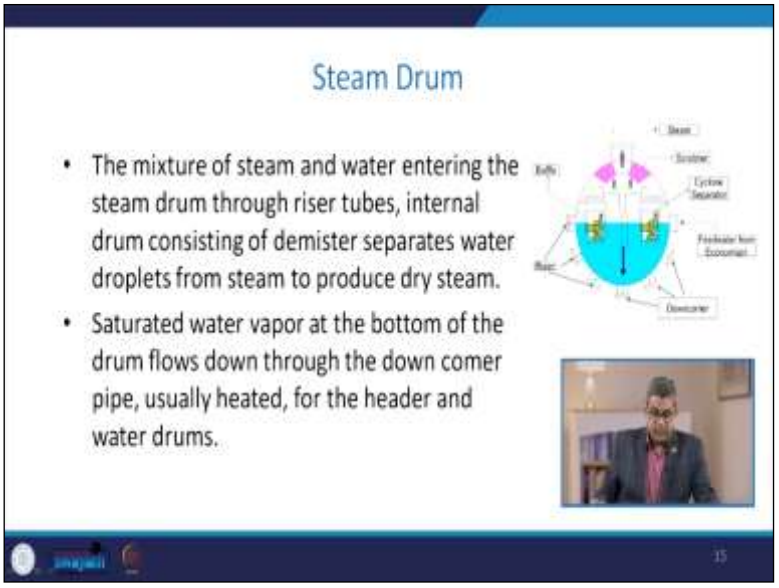

Let us talk about the steam drum. The steam drum is an integral part of the steam generation unit because it carries the two phases. One is this steam or vapor phase; another one is the liquid phase concerning the water. And also, it serves as the source for the separation of steam-water. It also carries steam in it as well as water. So, ah, one can say that a steam drum is a standard feature of the boiler water pipes.

It is a reservoir of water or steam at the upper end, and the water at the lower end you can see this is the steam drum where you see the reservoir for the water, and here you see the reservoir for the steam. This drum keeps the steam produced in the water tubes and acts as a phase separator for the mixed steam or water you see that we talked about that we need to separate the steam from the water.

So, this is the way the density difference between hot and cold water; helps in the accumulation of water or saturated steam into the steam drum. This is what you can say, the answer to the problem of how the steam is being separated from the water.

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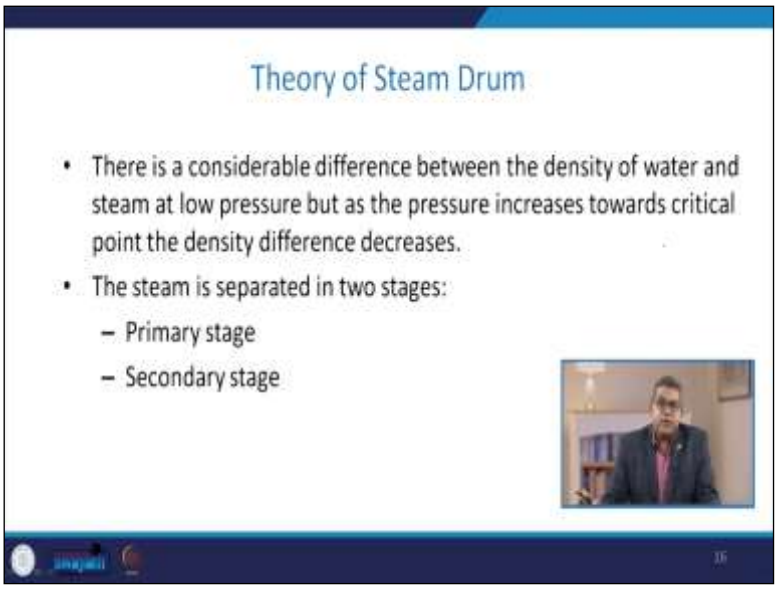

The integral part of your steam drums is enlisted over here, the mixture of steam and water entering the steam drum through the riser tubes. So, you can see these are the riser tubes through which the steam and the water are entering the drum. An internal drum consisting of a demister separates the water droplets from the steam to produce the dry steam. Saturated water vapors at the bottom of the drum flow down through the downcomer. Here, this is the downcomer usually heated for header and water drums.

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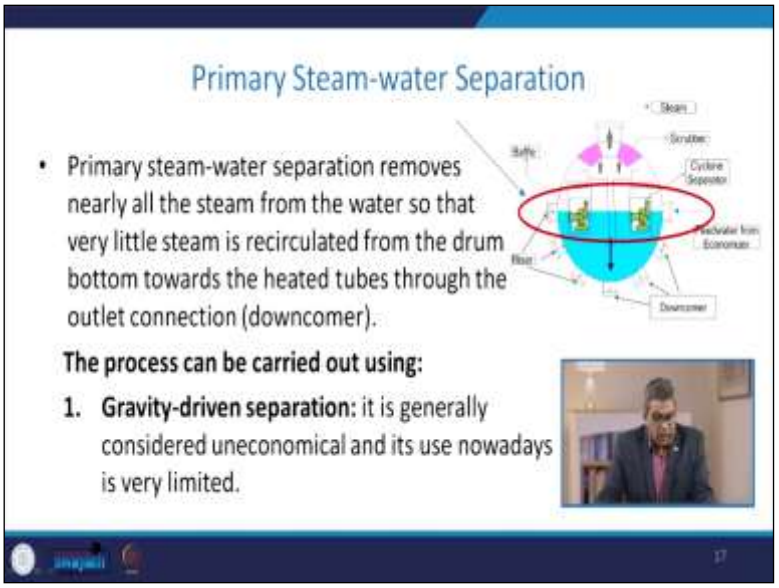

When we are talking about the theory of steam drums, there is a considerable difference between the density of water and steam at low pressure, but as the pressure increases towards the critical point, the density difference decreases. So, steam is separated into two stages one is the primary stage, and the second one is the secondary stage.

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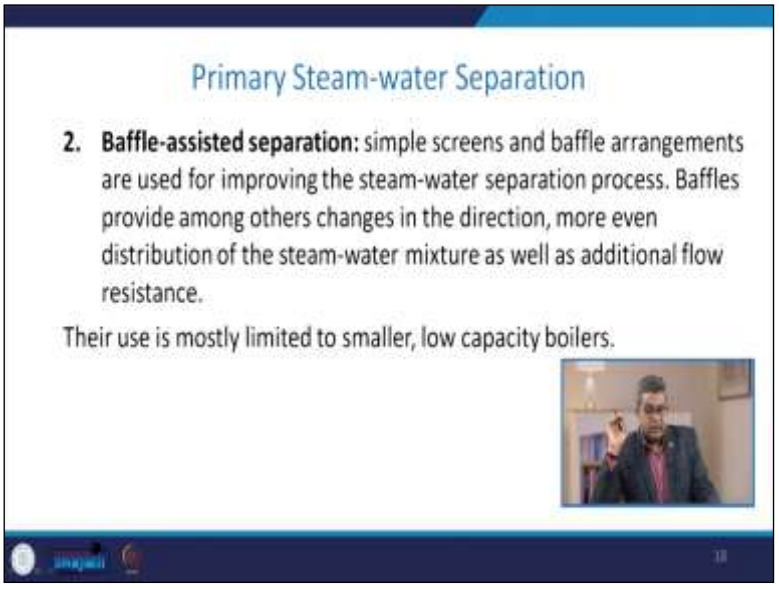

when we talk about the primary stage, primary steam-water separation, or a primary stage, the primary steam water separation removes nearly all the steam from the water. So, that very little steam is recirculated from the drum bottom or to the downcomer towards the heated tubes through

the outlet connection that is the downcomer. This process can be carried out using either gravity-driven separation. It is generally considered uneconomical, and its use nowadays is minimal.

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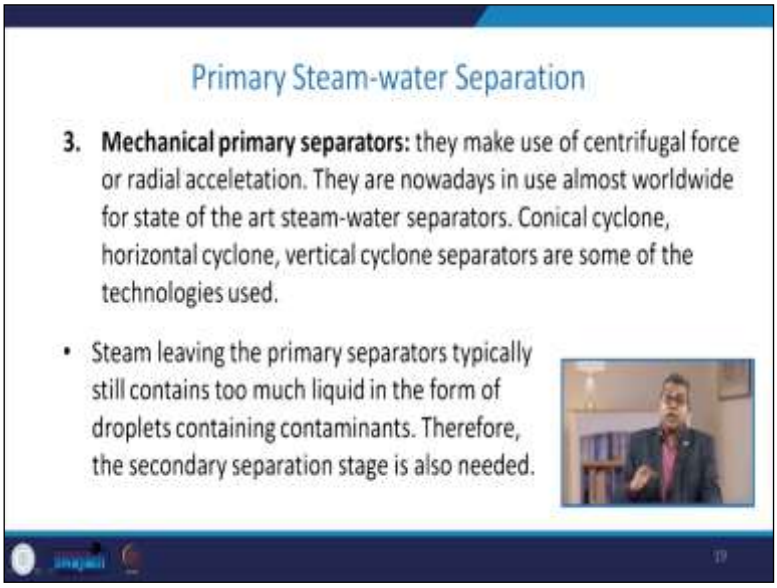

Another is the baffle assisted you to see there are several baffles over here. So, baffle assisted separations. Simple screens and baffle arrangements are used for improving the steam-water separation process. Baffle provides, among other changes in the direction more even distribution of the steam-water mixture as well as additional flow resistance. Their use is mainly limited to smaller and for low-capacity boilers.

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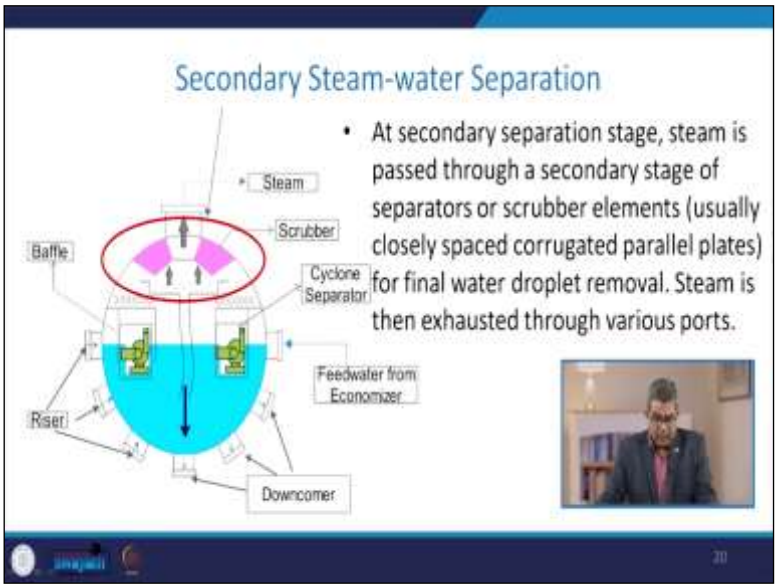

The third one is the primary mechanical separators. make use of centrifugal force or radial acceleration are nowadays in use almost worldwide for a state of art steam-water separators. Conical cyclone, horizontal cyclone vertical cyclone separators are some of the technologies being used for the set purpose. The steam leaving the primary separators typically contains too much liquid in the form of droplets containing contaminants. Therefore the secondary separation stage is also needed.

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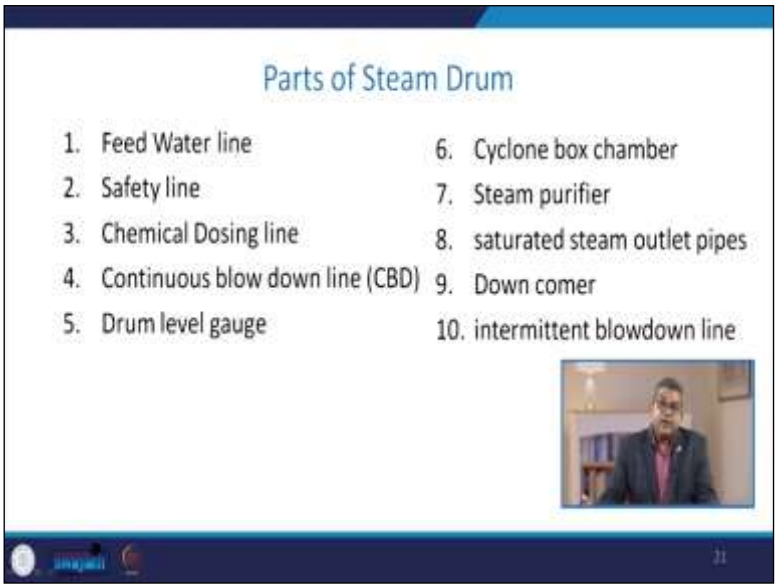

Now, in this particular figure. This is your secondary steam-water separation system. At the secondary separation stage, steam is passed through the second stage of the separator or scrubber here; you see that scrubbers are there. Usually, the closely spaced corrugated parallel plates. By this width are separating for final water droplets removal. Steam is then exhausted through the various ports. So, you can see that steam is moving out from here.

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So, ah, there are various parts of steam drums. One is the feed water line safety lines because it carries the steams. So, and sometimes the pressurized steam, so steam safety linessometimes you may require to put forward some doses in the steam drums. So, there must be one chemical dosing line. Then the continuous blowdown lines or CBD must be there. So, that is any kind of a sludge, etcetera, because the recirculating water is there. So, sludge accumulation may be scaled accumulation may be there.

So, you must have a continuous blowdown line to remove all those sludge scales, etc., to improvise the efficiency because, ultimately, it does not have any economic value. Then the drum level gauge is again very important to assess the water level as well as a steam cyclone box chamber steam purifier we have already discussed, then saturated steam outlet pipe here and then downcomers and intermittent blow down lines. So, all these are an integral part of your steam drum.

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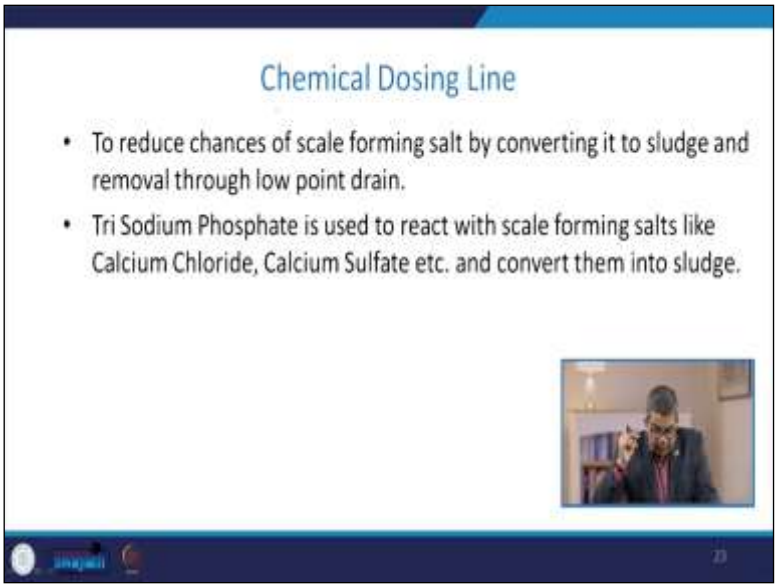

see the safety walls when again is the very integral part of the boiler or steam generation unit are typically used for boiler overpressure protection. Various devices have been used to prevent boiler damage or boiler explosion because it is a pressurized vessel pressure vessel. So, if excessive pressure is being built up because of the pressure-temperature and volume effect, sometimes, if we do not have these types of safety devices, it may be dangerous for the person who is working in and around.

So, are the safety valves typically used for boiler overpressure protection and other applications like downstream pressure reducing control. Although their primary role is for the safety valves are also used in the process operation to prevent product damage due to excess pressure.

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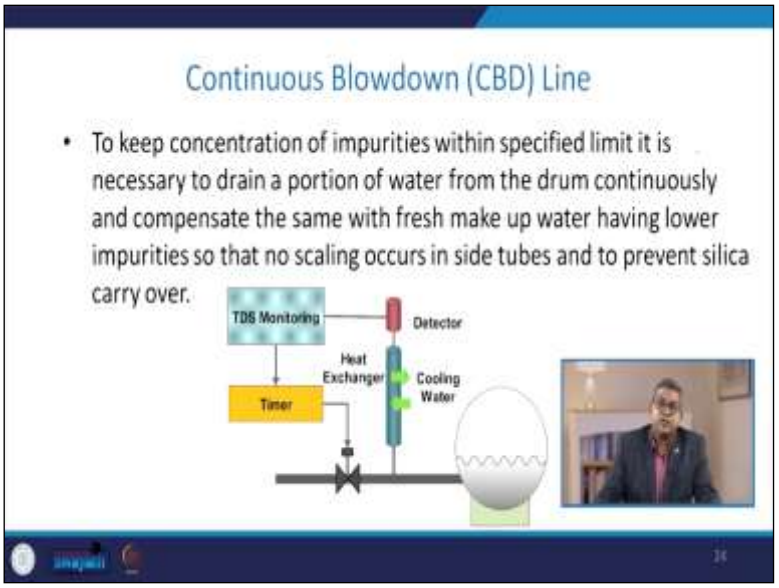

Another thing is that chemical dosing lines reduce the chances of any kind of scale formation by converting into the sludge and removal through the low point drain. So, the trisodium phosphate is usually used to react with the scale-forming salts like calcium chloride, calcium sulfate, etcetera and convert them into sludge.

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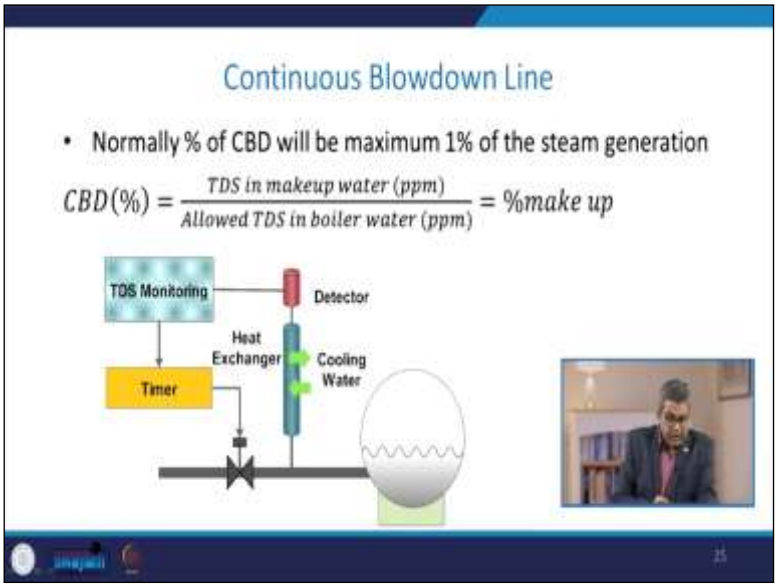

Another thing which we need to address is the continuous blow down the line. To keep the concentration of impurities within the specified limit, it is necessary to continuously drain a portion of water from the drum and compensate the same with fresh makeup water having the lower

impurities. The scale formation within the system can be minimized within the side tubes, and the silica carryover can be prevented.

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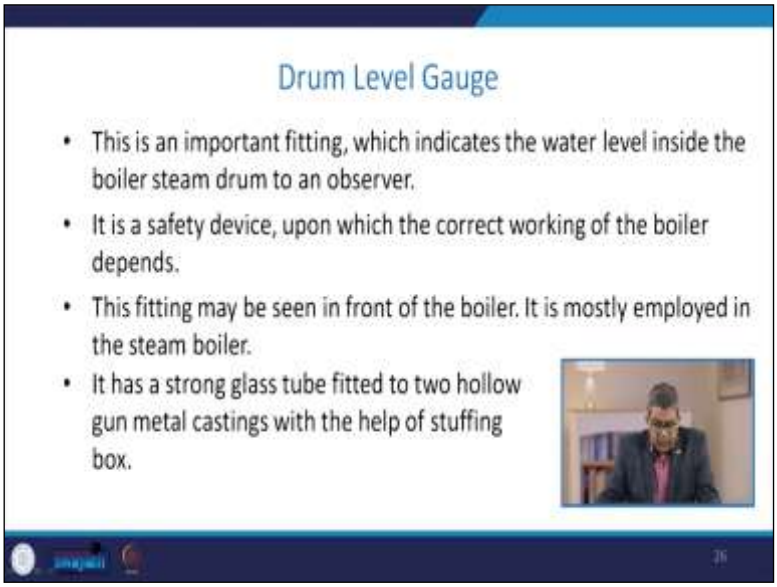

Here you see that some of the integral parts of the continuous blowdown line, the TDS monitoring system TDS stands for total dissolved solids. There must be a timer heat exchanger and a detector through which you can supply the chemical dosing and continuous chemical blowdown, and you can assess that at what time you need to start the blowdown. Normally, the percentage of continuous blow down the line or CBD will be a maximum of 1% of the steam generation.

So, the continuous blowdown in percentage can be represented through this mathematical representation that is the TDS that is the total dissolved solids in makeup water in parts per million that is PPM over allowed TDS in boiler water PPM and that is the percentage makeup.

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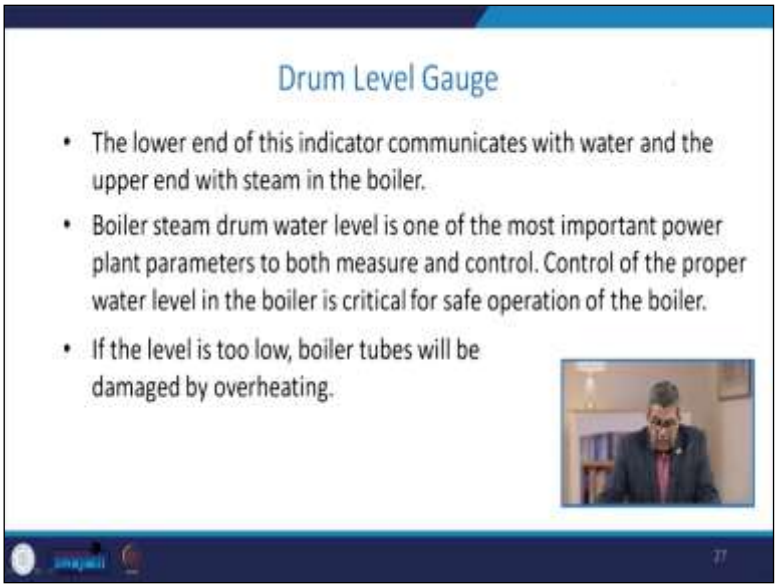

Then we must have a drum level gauge. This indicates the water level inside the boiler steam drum to an observer. It is some sort of a safety device upon which the correct working of the boiler depends. This fitting may be seen in front of the boiler, and it is mostly employed in the steam boiler. Usually, it has a strong glass tube fitted in two hollow gunmetal casings like this with the help of a stuffing box.

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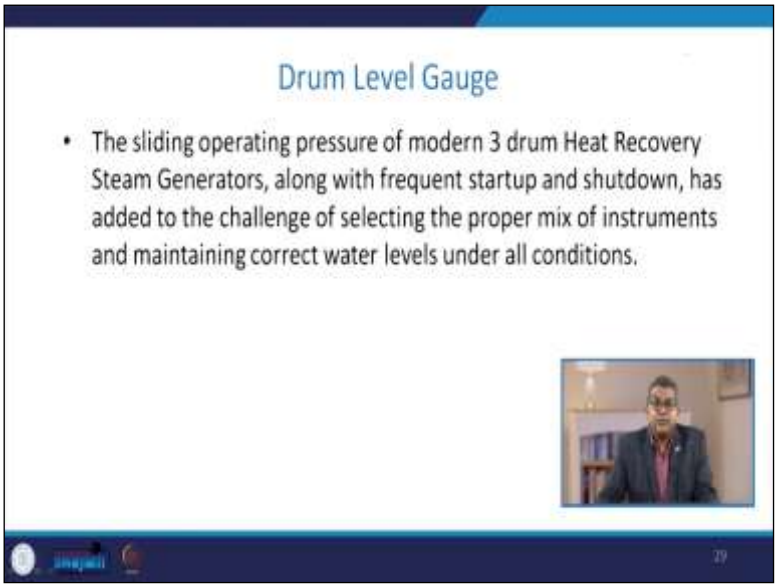

The lower end of this drum level gauge communicates with water, and the upper level represents the steam in the boiler. Boiler steam drum water level is one of the most important power plant parameters to both measure and control. Control of the proper water level in the boiler is critical

for the safe operation of the boiler. There are two consequences when maybe the water level in the boiler is low or high.

Now, suppose the level is too low. In that case, the boiler tubes will be damaged by overheating because they may get exposed to the heating lines, and because of inadequate heat transfer media with respect to the water may start, I mean overheating, and over the period of time when if either you introduce the freshwater or sometimes it may bend because of the heat impact or expansion of the metal and it may create a problem.

And sometimes it is so harmful that it may damage and the boiler may get explode. Sometimes, the level is too high. So, stream separators will not function properly, and the temperature control will be extremely difficult, and the superheater tubes and turbine could be damaged by moisture or water treatment carryover chemical carryover. The steam and water may get separated to the density difference if you notice.

So, that separation may not take place, and sometimes the steam carryover or water droplet carryover may cause excessively, and sometimes you may not notice this particular problem in the boiler, but you may see the impact of these carry over to the point of use where you are using the steam, so that is why the proper level is quite essential. In addition, poor level control will also adversely affect the drum pressure control, and that is again very important.

Because the pressure aspect is again very crucial, if you are not getting the steam at the desired pressure, you may experience the problem. The sliding operating pressure of modern three drum heat recovery steam generators, along with the frequent startup and shutdown, has added to selecting the proper mix of instruments and maintaining the correct water level under all conditions.

there is a saturated steam outlet pipe. The saturated steam is the steam in equilibrium with water; that is the steam that holds all the moisture and still remains in the vapor. So, saturated steam can purge process equipment, perform other functions, or be superheated. As long as the steam and the

water are in contact with each other, the steam is in the saturated conditions because of the phase equilibrium concept.

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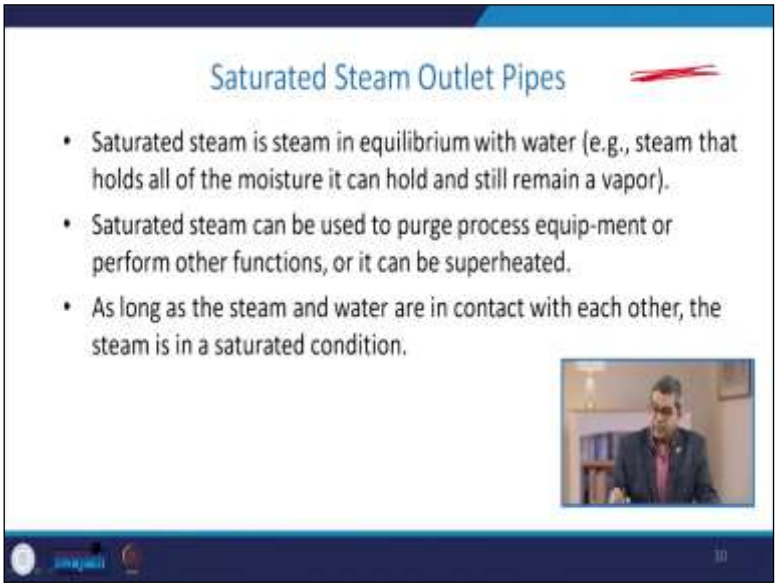

Here you can see the water and the steam. So, these are in equilibrium. So, this is this zone will always be as a saturated zone.

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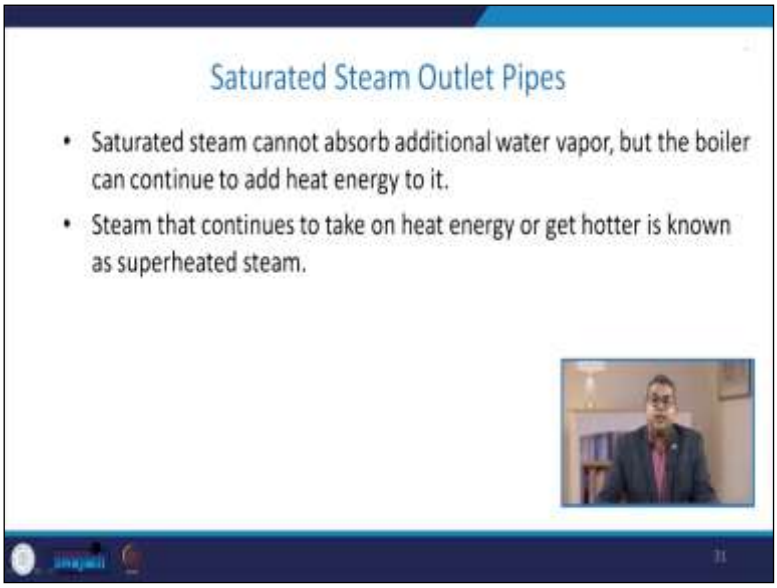

Saturated steam cannot absorb additional water vapors, but the boiler can continue to add heat energy to it. Steam that continues to take up a take on heat energy or get hotter is known as superheated steam; this is the usual phenomenon. Let us talk about the downcomer. The

downcomers are the tubes that transfer water from the steam drum to the mud drum. As the cooler water descends from the steam drum and flows through the downcomer, it picks from the firebox and replenishes the water supply to the mud drum.

Again, one important point of the boiler is the boiler's feed water supply. It is, you can say, the heart of the boiler. The quality of water which is supplied into the boiler is extremely important, and it must be at the corrected temperature, usually say around 80-degree Celsius, to avoid any kind of a thermal shock to the boiler.

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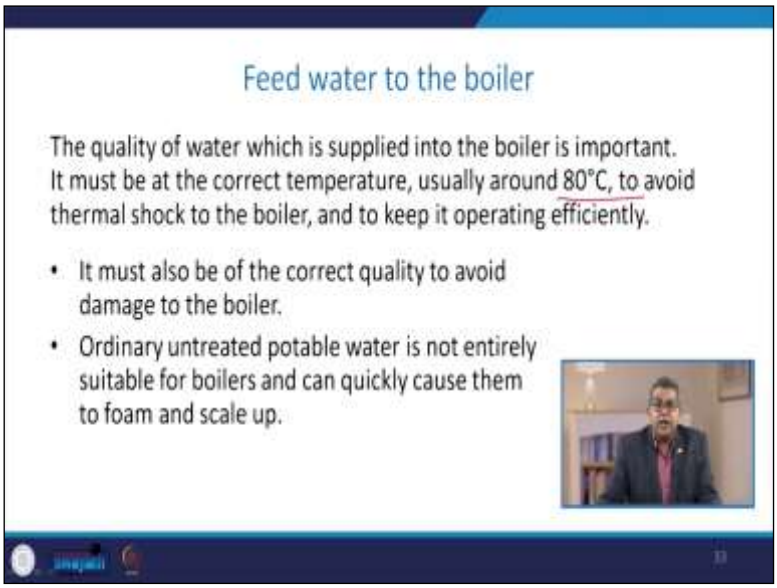

And keep it operating efficiency the reason is that sometimes boiler operates say around 200-degree Celsius and if you supply the normal water to normal water say suppose maintain at 25-degree Celsius then there may be a chance of thermal shock because of the larger delta T. To avoid this the feed water temperature must be corrected properly also it must be having a correct quality to avoid any kind of a damage to the boiler.

Ordinary untreated potable water is not entirely suitable for boilers and quickly causes them to form and scale up, reducing boiler efficiency. Thereby, if the boiler is less efficient, you may face severe economic loss, steam would become dirty and wet, and sometimes it is not usable. So, the life of the boiler would also be reduced similarly. So, feedwater treatment and heating take place in the feed tank, which is usually situated high above the boiler to utilize the gravitational factor.

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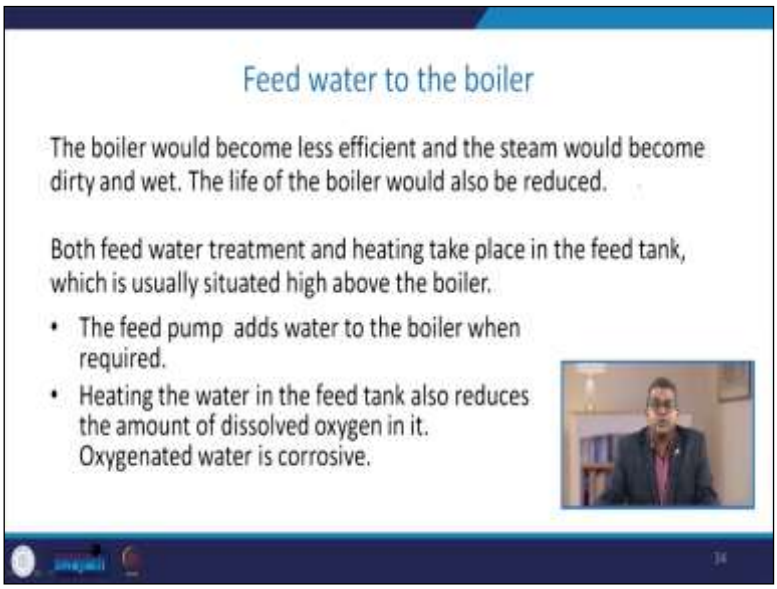

The feed pump adds water to the boiler when it is required, and heating the boiler in the feed tank also reduces the amount of dissolved oxygen in it obviously, we discussed a lot about how oxygenated water is corrosive in nature.

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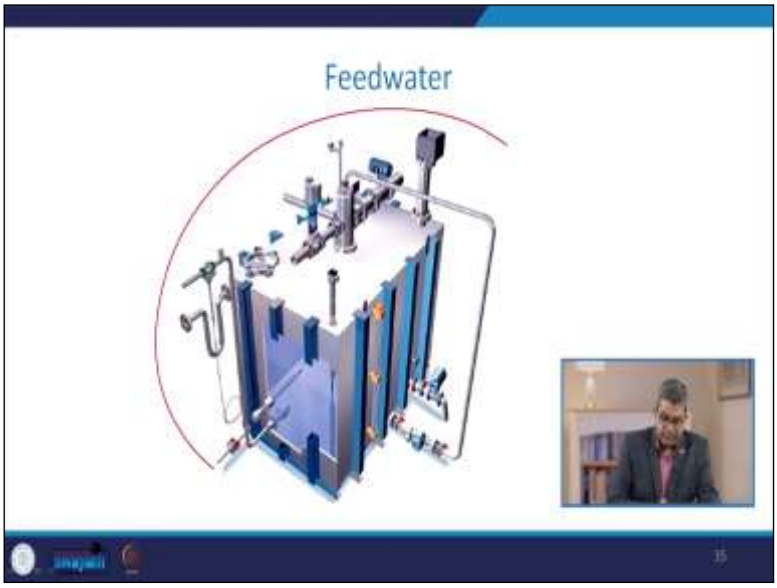

Now, this is the typical feed water tank you see, and there are various lines in this. There are inlet lines heating lines, outlet lines, and temperature control safety devices. All these things are here.

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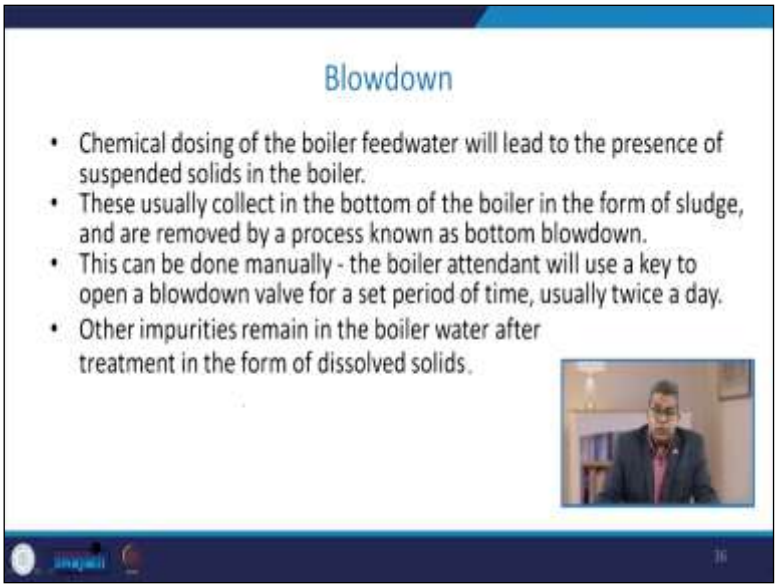

The blowdown; the chemical dosing of boiler feed water leads to suspended solids in the boiler. These usually collect in the bottom of the boiler in the form of sludge and are removed by the process known as bottom blowdown. This is sometimes carried out intermittently, and sometimes this can be done manually by the boiler attendant, who uses usually use a key to open the blowdown valve and set a period usually twice a day, thrice a day, depending upon the nature of the sludge is formed. Other impurities remain in the boiler water after treatment in the form of dissolved solids.

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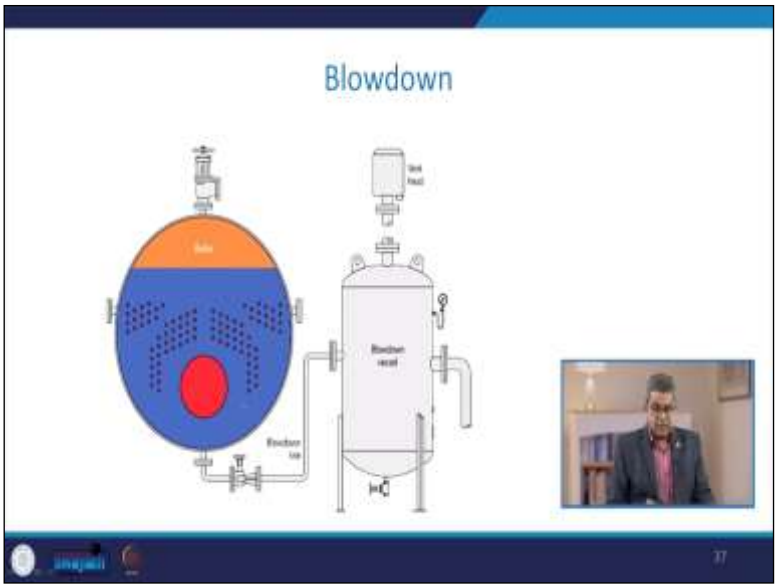

Here you see that this is the blowdown vessel, and this is the boiler, you see that this is the steam chest, and this is the waterline, and this is the key through which you can open the blow down the line, and since this particular, the entire content of this boiler is maintained at a very high temperature. So, you cannot discharge all these things altogether. So, um, it is discharged to this blowdown vessel. Usually, a flashing may occur because if it is at high pressure, then in that case, the flashing may occur.

So, excess vapors can be discharged in this way, and there is a pressure measuring device through which you can measure the pressure and thus to operate the vent head, and you can discharge the blowdown later on.

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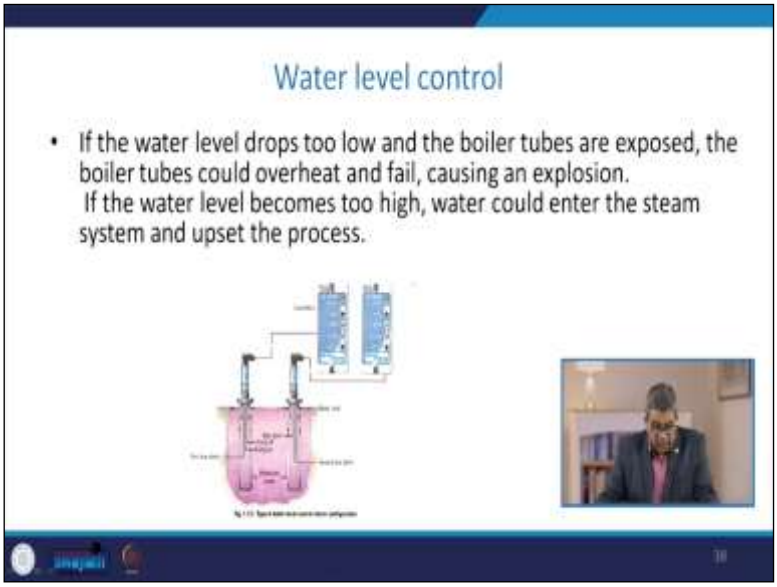

We have discussed about the water level controller in the previous section this is the typical you can see the boiler level control and alarm configuration always it is cubed with the alarm.this is fitted with the boiler shell and these are the protection tube because the quality of the steam and the safety of boiler it always depends on the accurate water level. So, we see that if the level is too low, the tubes could definitely overheat may cause the explosion if too high then carry over me take place.

Condensate in the boiler is again very crucial. The condensate has a substantial economic value whenever you are using the steam, and if it is condensed, you have invested a lot for water

purification, demineralization, and deionization. So, it carries value. So, the recovery of this condensate is extremely important. When we talk about the flow of steam to the plant, when steam condenses, its volume reduces, resulting in a localized reduction in pressure.

This pressure drop through the system which creates the flow of steam through the pipe the steam quality is again very important. It is important to ensure that the steam leaving the boiler is delivered to the process in the right condition.

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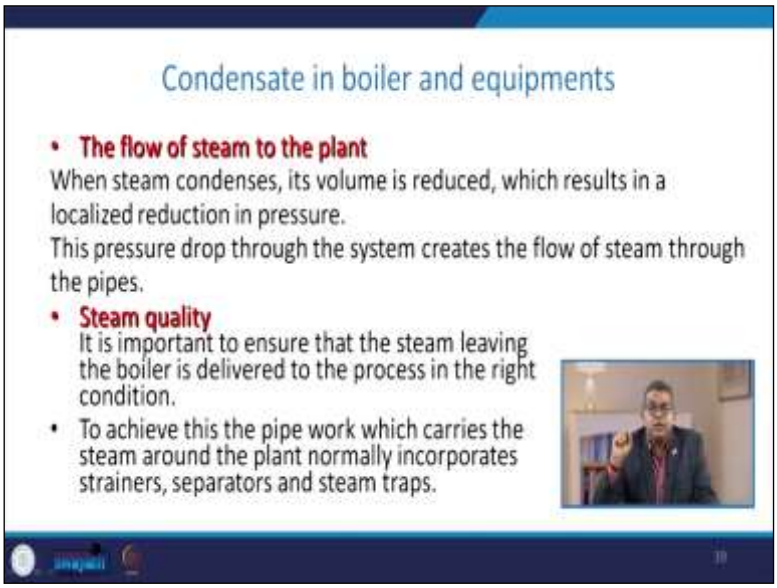

To achieve this, the piping work that carries the steam around the plant normally incorporates the various kinds of stainer separate or steam traps. The role of the stainer is just because over time with prolonged uses of these piping networks, some amount of debris may get deposited, due to the rusting of the pipe (corrosion of the pipe). If the small metal particles get entrapped in the steam and if it is used with any reactant by direct steam sparging. In that case, it may be very dangerous because these metal may cause the catalytic reaction and thermal runaway reaction or catalytic runaway reaction may take place. To eliminate this issue, strainers are placed in the steam line, which captures various kinds of a debris, etc.

When the steam from the distribution system enters the steam using the equipment, the steam will again give up energy either by warming up the equipment or continuing to transfer heat to the process. So, as steam loses heat, it turns back into the water that is the condensate.

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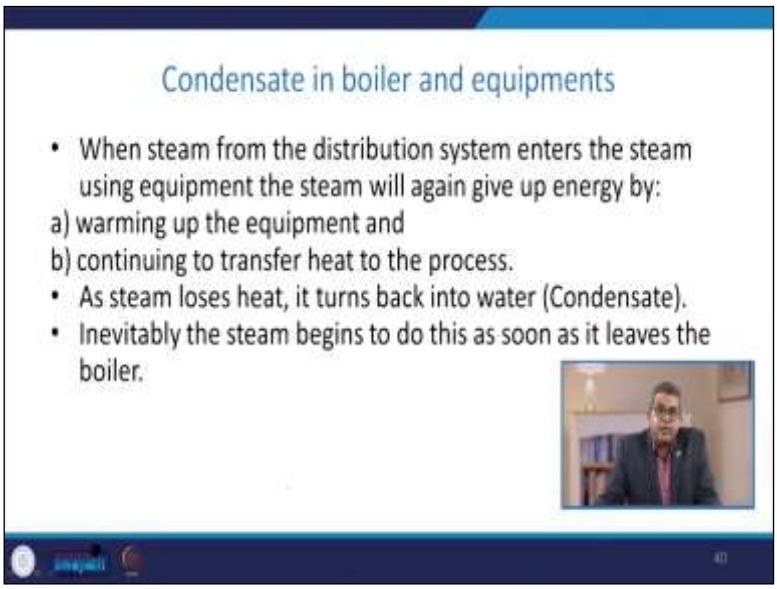

Inevitably the steam begins to do this as soon as it leaves the boiler. So, the temperature at the start is very high, and the pressure supports it, so it may not be possible at the end exit level of the boiler, but later on, it is a common phenomenon.

Condensate removal: The condensate must be removed from the lowest point in the distribution piping network for a variety of reasons.

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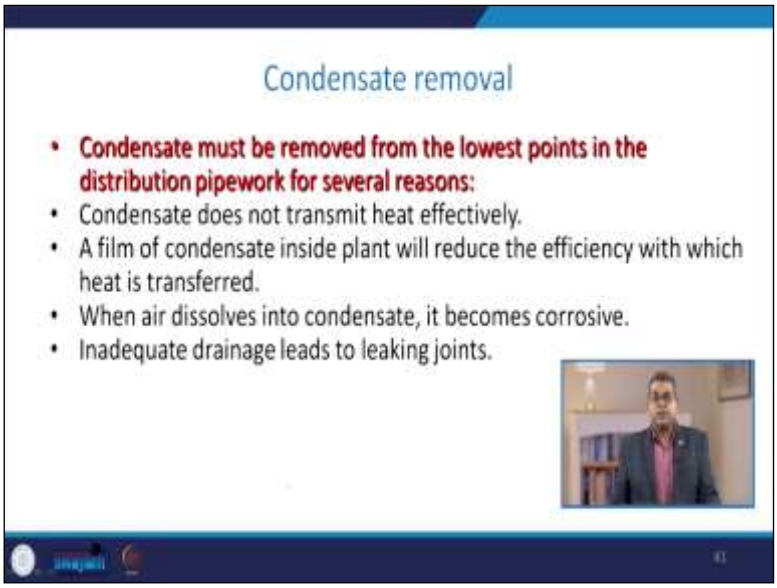

Because this condensate does not transmit heat effectively, a film of condensate inside the plant will reduce the efficiency with which the heat is transferred.when air is dissolved into condensate,

it becomes corrosive, and inadequate drainage may lead to inadequate drainage the leaking joints. So, in this particular lecture, we discussed the various aspects of steam drums, the integral part of the steam chest integral part of thethe drum with respect to the water level controller and other things.

We discussed the importance of condensate and how this condensate is formed and the importance of these condensate, especially in terms of the removal of these condensates.

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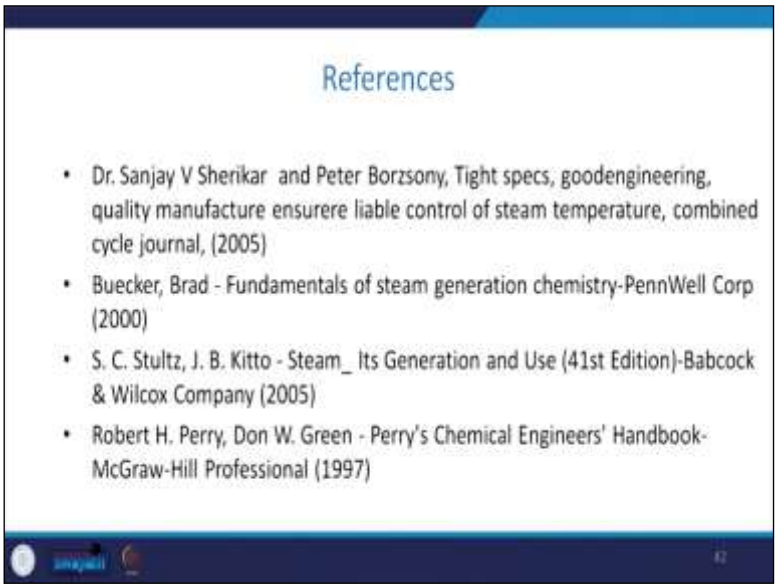

And if you wish to have a further reading then you can take the help of these references, thank you very much.