BU MEASUREMENT & ANALYTICS

Water Industry

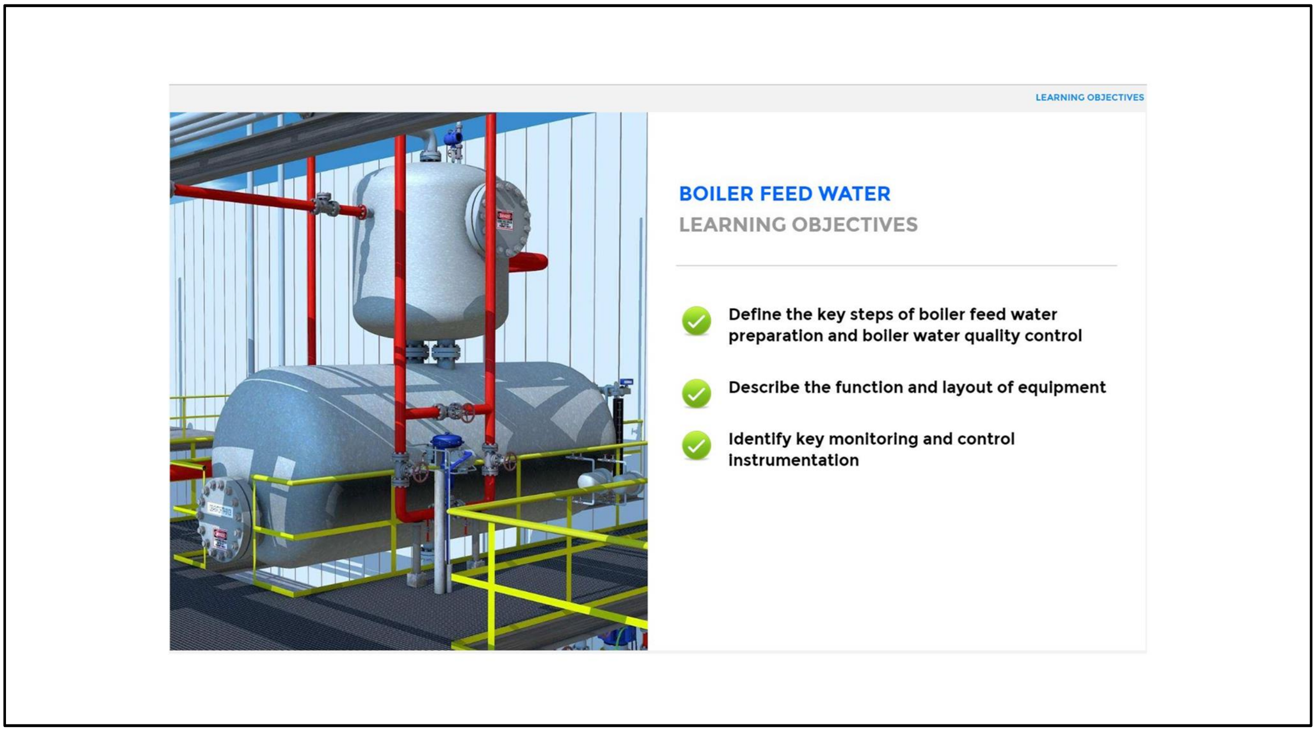
Boiler Feed Water

Welcome to Boiler Feed Water - this module is going to explain how boiler feed water is prepared and how boiler water quality is maintained.

For each step, we’ll be giving you a brief overview supported by a block flow diagram and a process description supported by a process flow diagram and 3D model images.

Where applicable, there’ll also be a process control description supported by a process flow control diagram.

At the end, we’ll give you a brief summary.



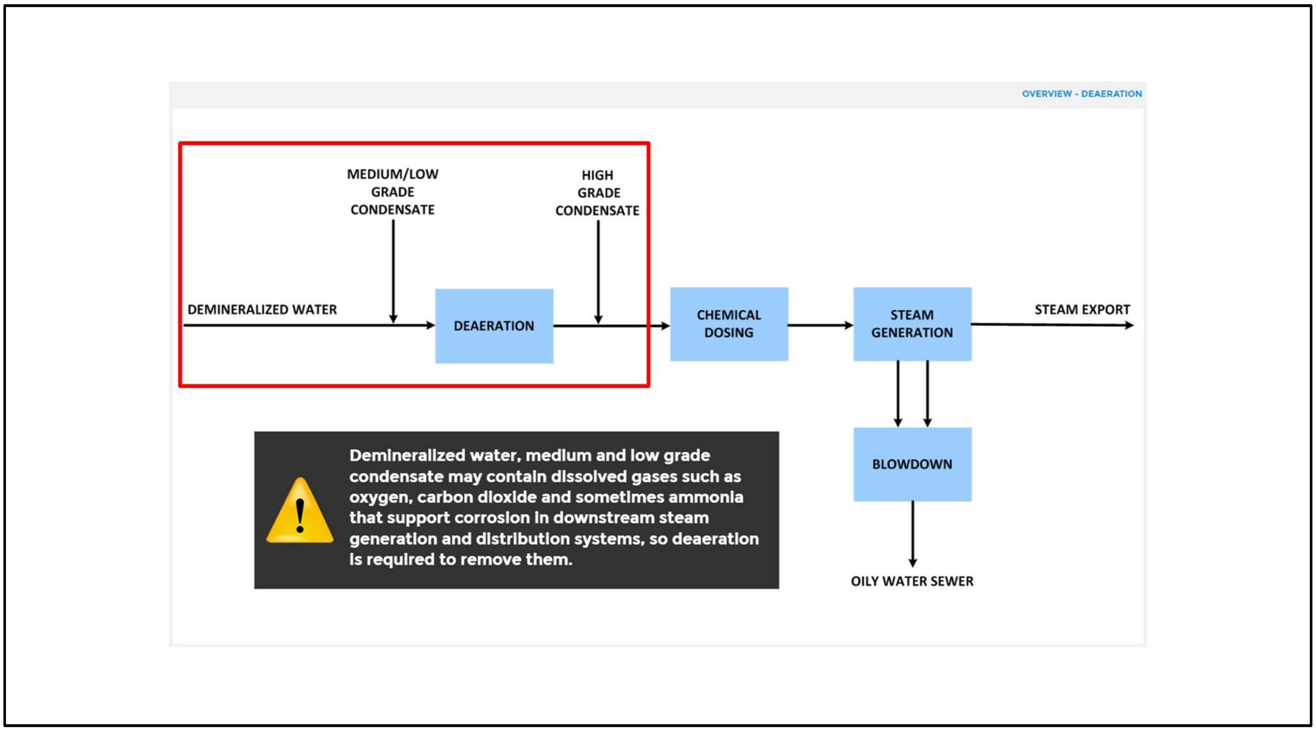
These are your learning objectives. Upon completion of this module, for boiler feed water preparation and boiler water quality control, you should be able to:

Define the key steps of boiler feed water preparation and boiler water quality control

Describe the function and layout of equipment

Identify key monitoring and control instrumentation

Our three key steps are Deaeration, Chemical Dosing and Blowdown.
We'll make a start with Deaeration.



The Deaerator has three principal sources of water:

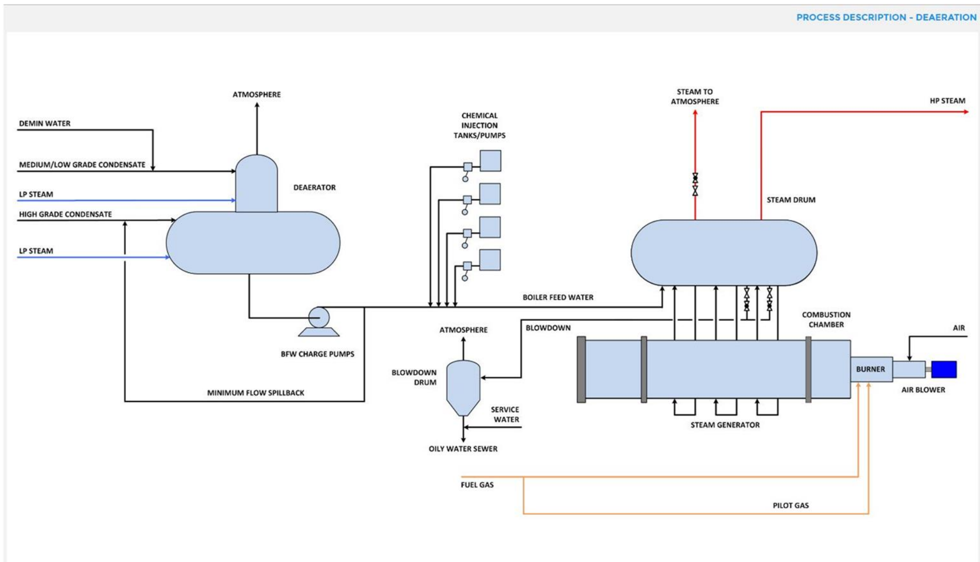
Demineralized water - this is purified water that has been through reverse osmosis and/or ion exchange treating

Medium and low grade condensate - this is potentially contaminated condensate recovered from medium/low pressure steam traps and medium/low pressure steam users

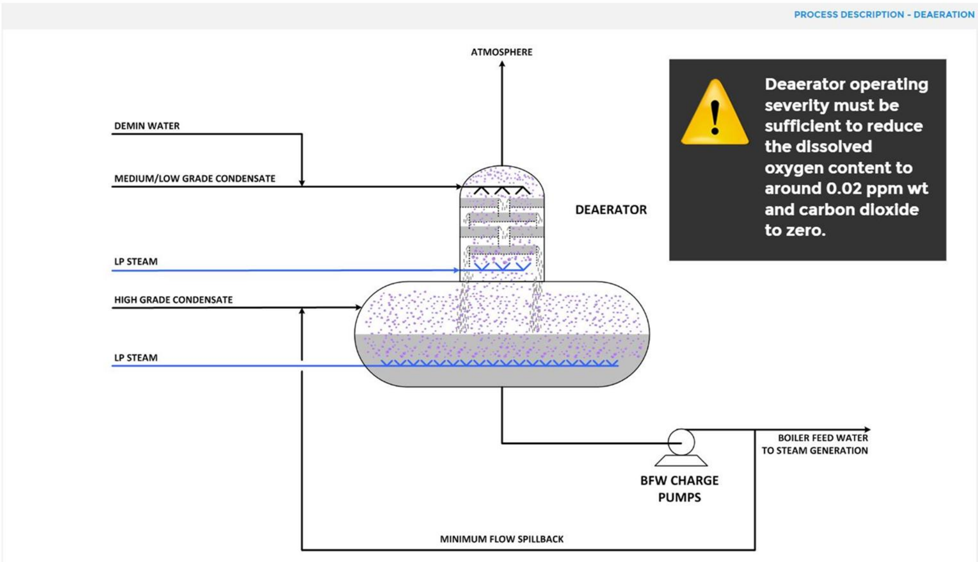
High grade condensate - this is uncontaminated condensate recovered from high pressure steam traps and high pressure steam users such as turbine exhaust condensers

Demineralized water, medium and low grade condensate may contain dissolved gases such as oxygen (O_2), carbon dioxide (CO_2) and sometimes ammonia (NH_3) that support corrosion in downstream steam generation and distribution systems, so deaeration is required to remove them.

High grade condensate does not generally require deaeration.



This process flow diagram shows the deaeration equipment followed by chemical dosing and steam generation.



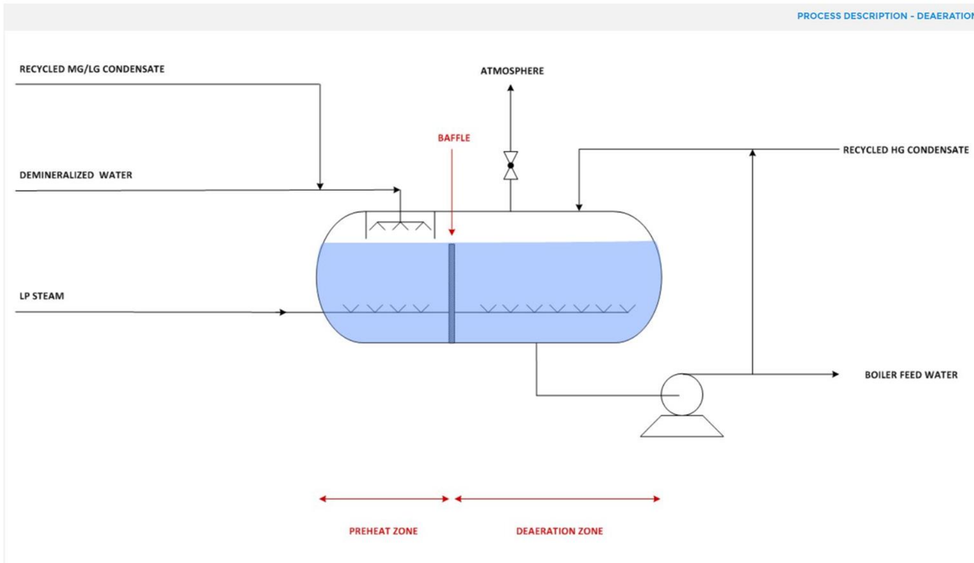
Dissolved gases are removed from recycled medium/low grade condensate and makeup demineralized water by stripping with low pressure steam in the upper section and then vented to atmosphere.

Stripped water (called boiler feed water or BFW) collects in the lower section. High grade condensate does not contain dissolved gases and is routed directly to the lower section.

Deaerator operating severity must be sufficient to reduce the dissolved oxygen (O_2) content to around 0.02 ppm wt and carbon dioxide (CO_2) to zero.

The boiler feed water in the lower section is kept hot by sparging with live low pressure steam.

Boiler feed water is withdrawn from the deaerator by vertically-mounted, low-to-medium volume, high-differential head, single-stage centrifugal pumps that require a minimum flow at all times - which is provided by a spillback system.

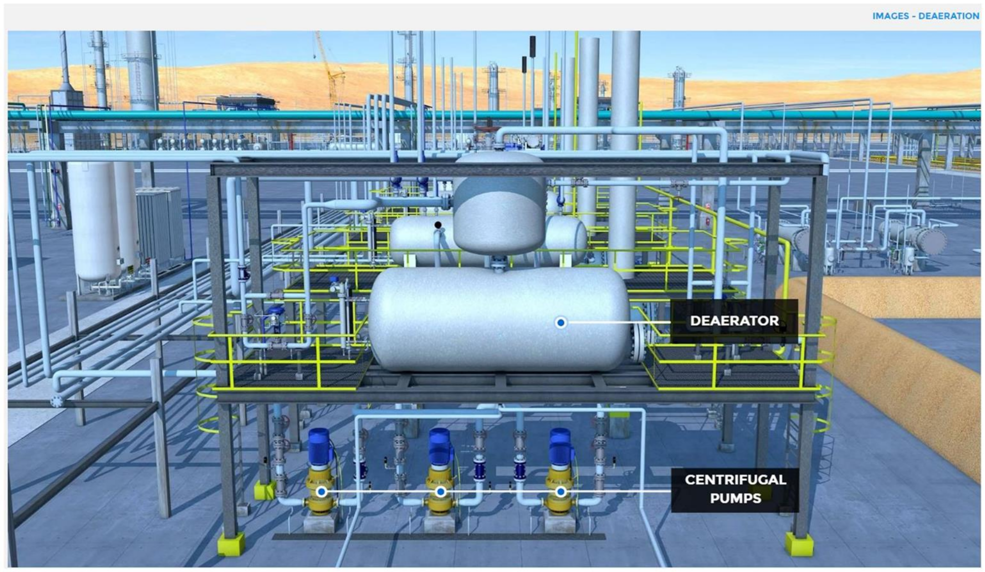


A second, less common type of deaerator has two compartments separated by a vertical baffle:

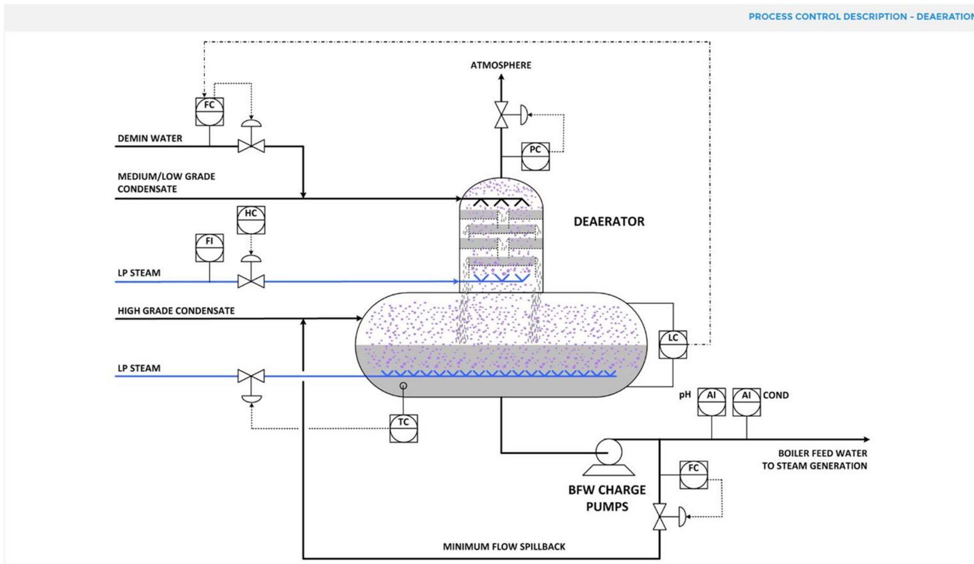
Demineralized water and recycled medium/low grade condensate are sprayed into the preheat zone where they are preheated to their saturation temperature through contact with steam from a submerged sparge pipe

Preheated water overflows a vertical baffle and enters the deaeration zone where steam from the sparge pipe strips out dissolved gases

Stripped gases and uncondensed steam are vented to atmosphere and deaerated boiler feed water is pumped (via chemical dosing) forward to the steam generation system



This image shows a typical deaerator with the high-differential head, single-stage centrifugal pumps in the foreground.



This process flow control diagram shows the principal monitoring and control instrumentation for the Deaerator.

The Deaerator level is maintained by a level controller that resets a flow controller in the demineralized water makeup line in a cascade control arrangement.

Low pressure steam is added to the top section manually by the operator with reference to an upstream flow indicator.

Usually, only a small flow of steam is required - sufficient to ensure the pressure controller is just open and venting stripped gases to atmosphere.

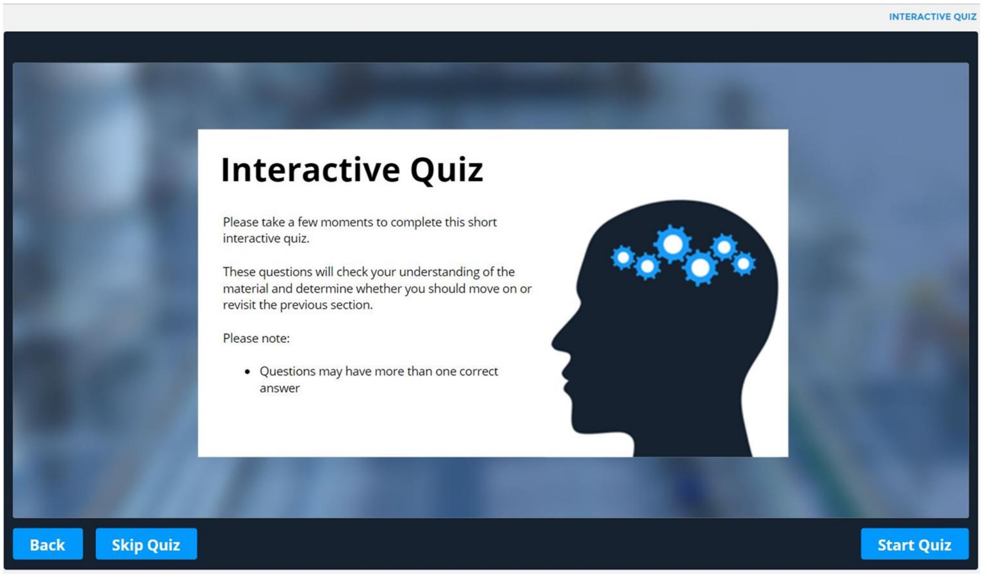
The operator may also base stripping steam flow adjustments on the indication of the conductivity analyzer, located in the deaerated water outlet line.

A temperature controller in the bottom section keeps the deaerated water hot by sparging with live steam.

This ensures the deaerated water doesn’t have a quenching effect in downstream steam raising equipment.

The Boiler Feed Water Pumps typically develop a high head, necessitating a flow be maintained through the pump at all times. This is provided by a minimum flow spillback.

An analyzer measures the pH of the deaerated water and this is used as a basis for downstream chemical addition.



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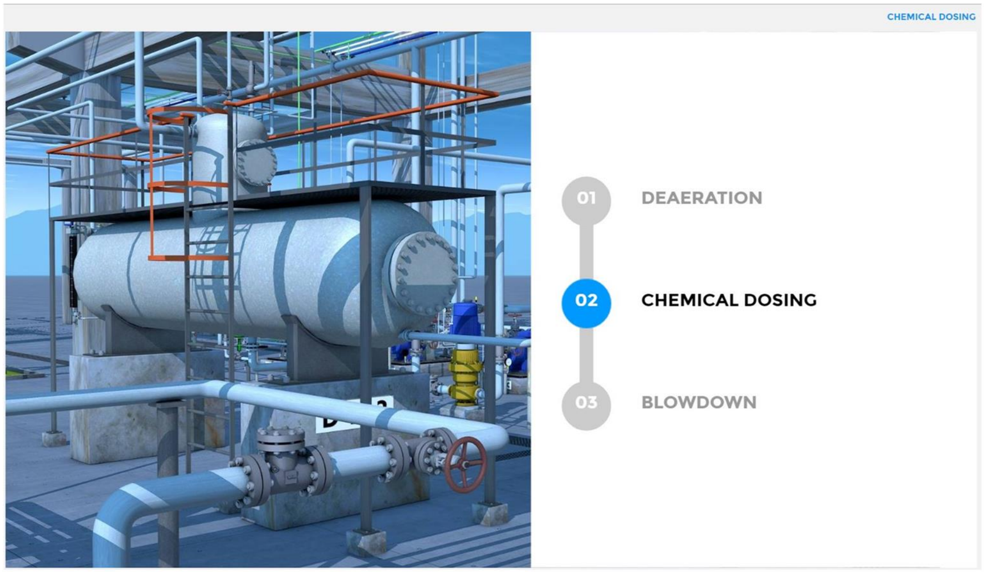
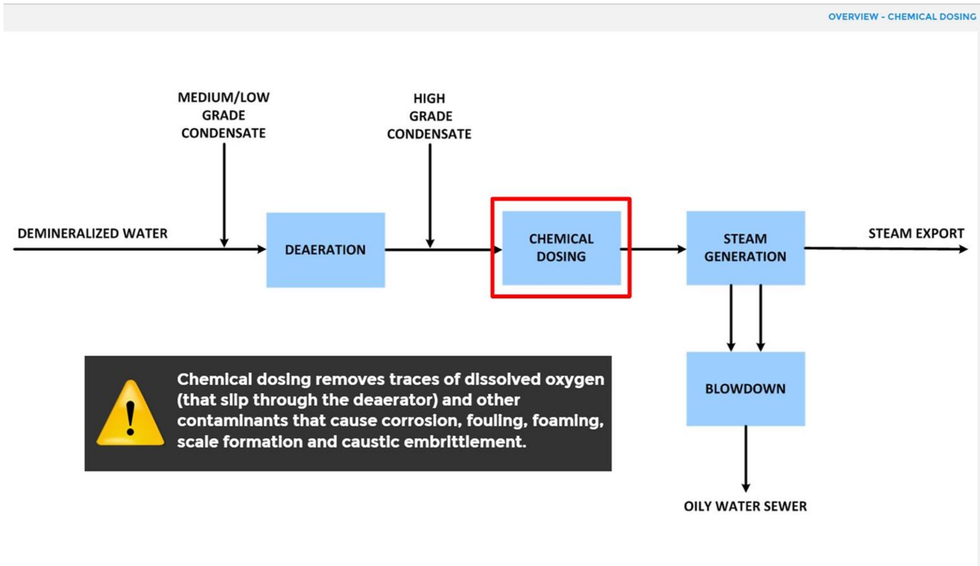
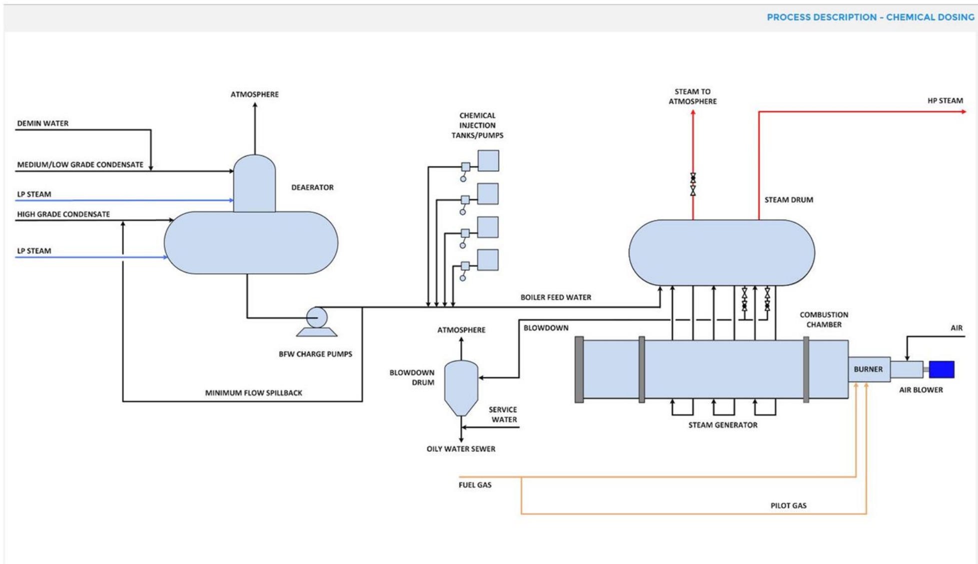


Our next topic is Chemical Dosing.



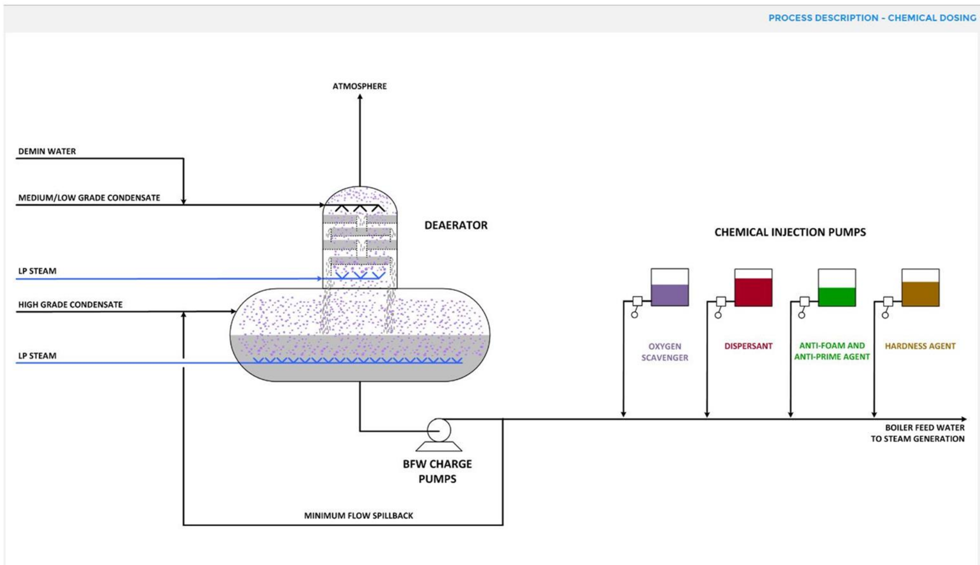
Chemical dosing removes traces of dissolved oxygen (that slip through the deaerator) and other contaminants that cause corrosion, fouling, foaming, scale formation and caustic embrittlement.



The process we're studying has four chemical dosing systems - others may have more, some may have fewer.

The dosing chemicals are typically held in containers, which can be conveniently replaced when empty.

The dosing pumps are of a reciprocating type, capable of injecting small metered amounts of chemicals at high pressure into the boiler feed water on its way to steam generation equipment.



We'll take a look at the chemicals typically injected - an oxygen scavenger, a dispersant, an anti-foam and anti-prime agent and a hardness agent.

Some systems may also add caustic to maintain an alkaline pH, thereby limiting corrosion.

Oxygen scavenger

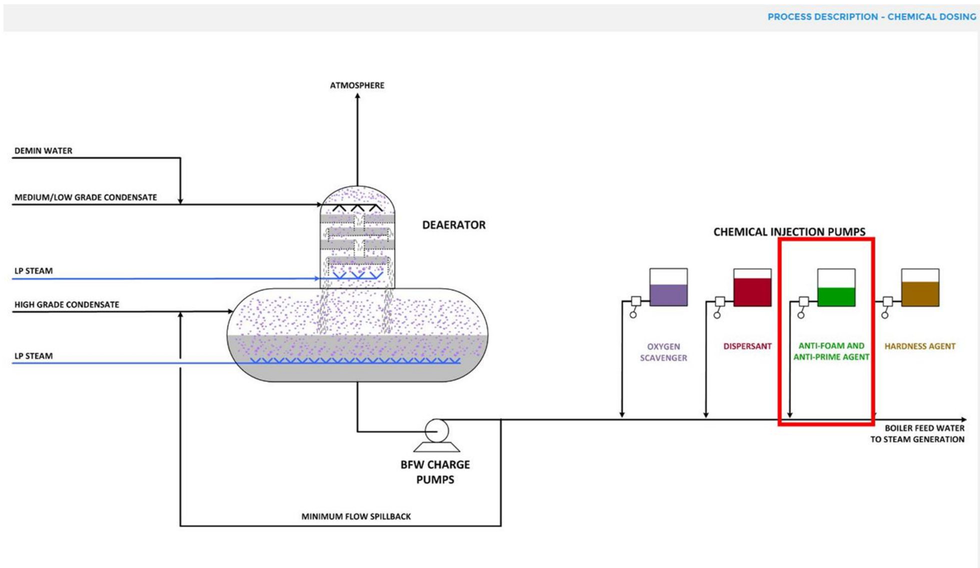
Although deaeration removes the majority of the dissolved gases, it is not 100% efficient and chemical dosing of the deaerated water with an oxygen scavenger is required in order to achieve target deaeration levels.

A commonly used oxygen scavenger is sodium sulfite (Na_2SO_3) which reacts with dissolved oxygen to form sodium sulfate Na_2SO_4 which is subsequently removed in downstream steam generation equipment by blowing down.

A less commonly used oxygen scavenger is hydrazine (N_2H_4).

Dispersant

A blend of natural and synthetic dispersants help mix the additive chemicals with the boiler feed water.



Anti-foam and anti-prime agent

Foaming occurs downstream in the steam drum when bubbles or froth build up on the surface of the boiler water.

Substances such as alkalis, oils, fats, greases, certain types of organic matter and suspended solids in the boiler water are conducive to foaming by strengthening the surface film surrounding the steam molecules.

If contaminants are found in the boiler feed water, the usual suspects are recycled condensate streams and its common practice to exclude these streams from the deaerator until the source of contamination is found and isolated.

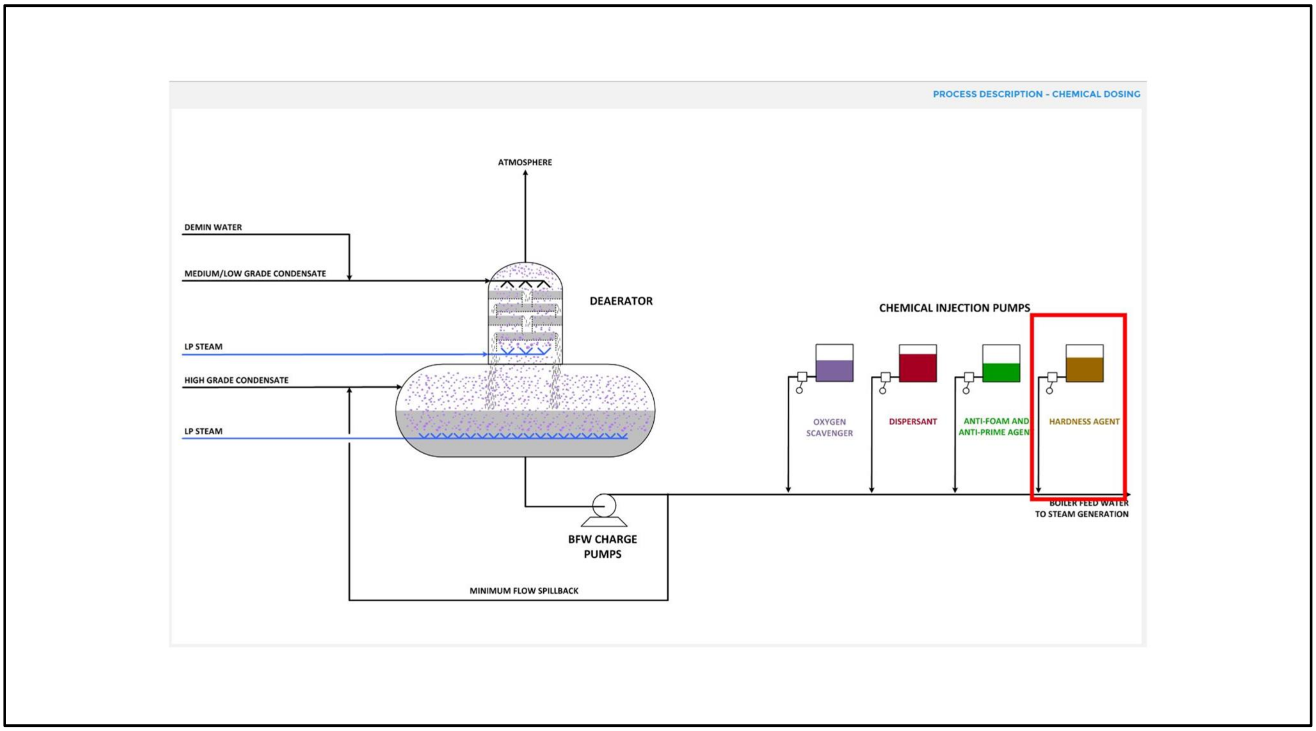
Priming is the carryover of varying amounts of droplets of water with the steam exiting the steam drum (i.e. foam and mist), which lowers the energy efficiency of the steam.

This leads to the deposit of salt crystals on superheater surfaces and turbine blades followed by in-service failures.

Priming is related to the viscosity of the water and its tendency to foam.

These properties are governed by alkalinity, the presence of certain organic substances and by total salinity or total dissolved solids (TDS).

The most common measure to prevent foaming and priming is to maintain the concentration of solids in the boiler water at reasonably low levels supported by injection of a chemical anti-foaming and anti-priming agent (a mixture of surface-active agents that modify the surface tension of the liquid boiler feed water molecules).



Hardness agent

Hardness salts are the cause of scale inside a boiler and if they are not prevented or removed regularly they will cause localized overheating.

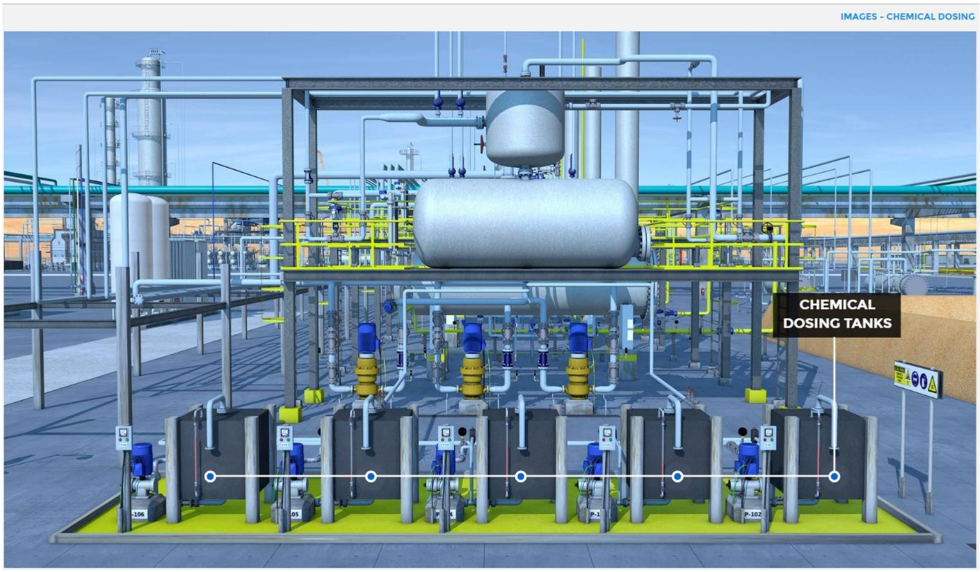
This can lead to a reduction in heat transfer efficiency and increased energy costs.

It can also result in a tube rupture that can cause serious equipment damage and extended downtime.

If the raw water makeup is properly demineralized and the recycled condensate is uncontaminated, hardness shouldn't be a problem.

If hardness salts are present, they can be treated with phosphates or carbonates.

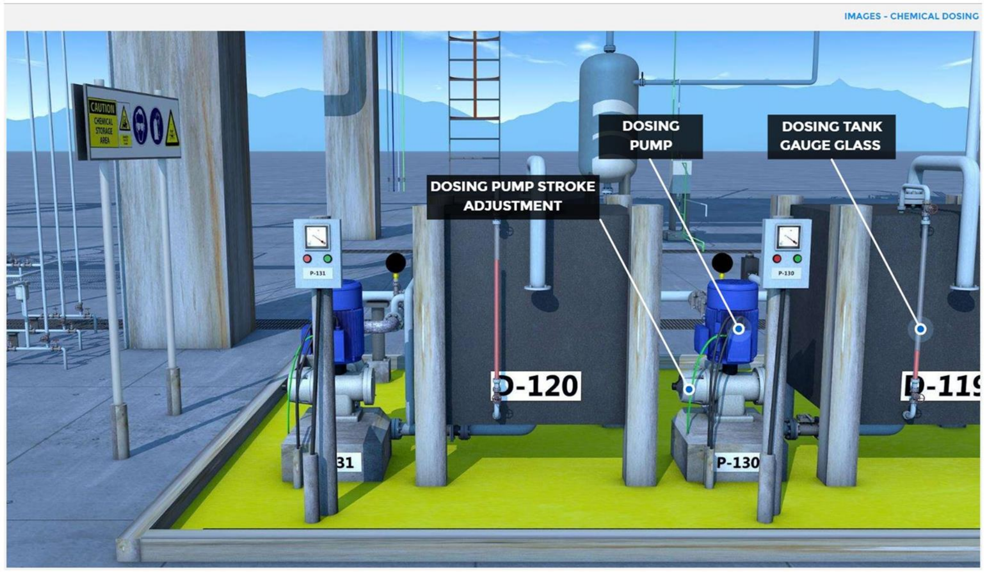
Phosphates are preferred as carbonates can lead to an increase in the levels of carbon dioxide in the steam and hence an increased corrosion risk.



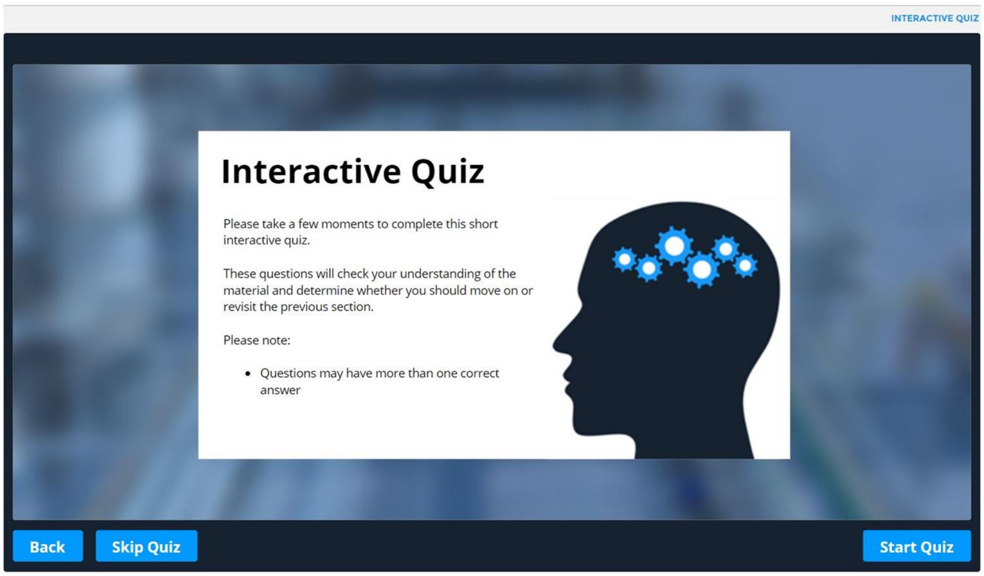
This image shows a group of five chemical dosing tanks and their associated pumps.

The amount of chemical injected is monitored by the operator recording the drop in tank level and setting the stroke of the pump.

The tanks and pumps have a tiled and bunded floor with segregated drainage in case of a spillage.



This close-up shows the dosing tank gauge glass and injection pump stroke adjustment.



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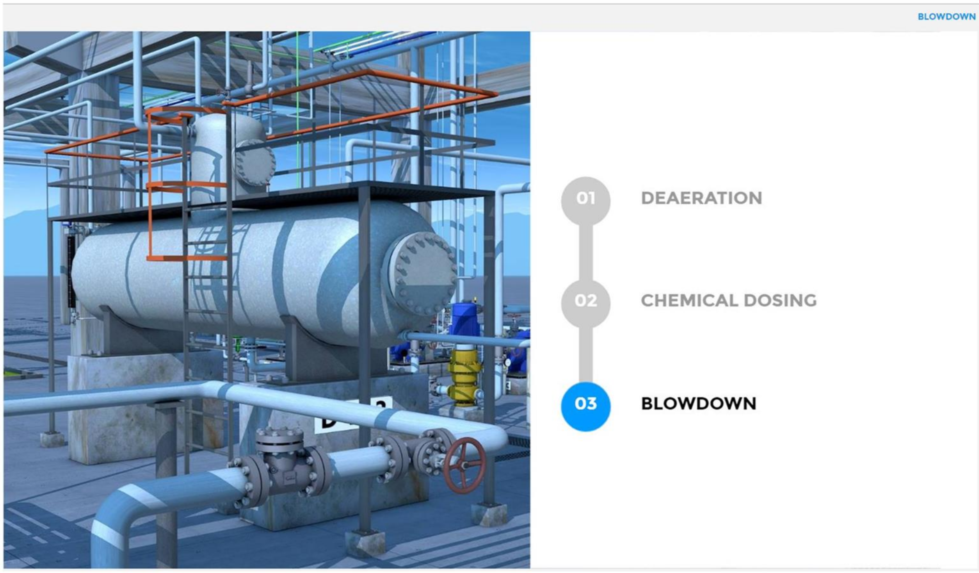
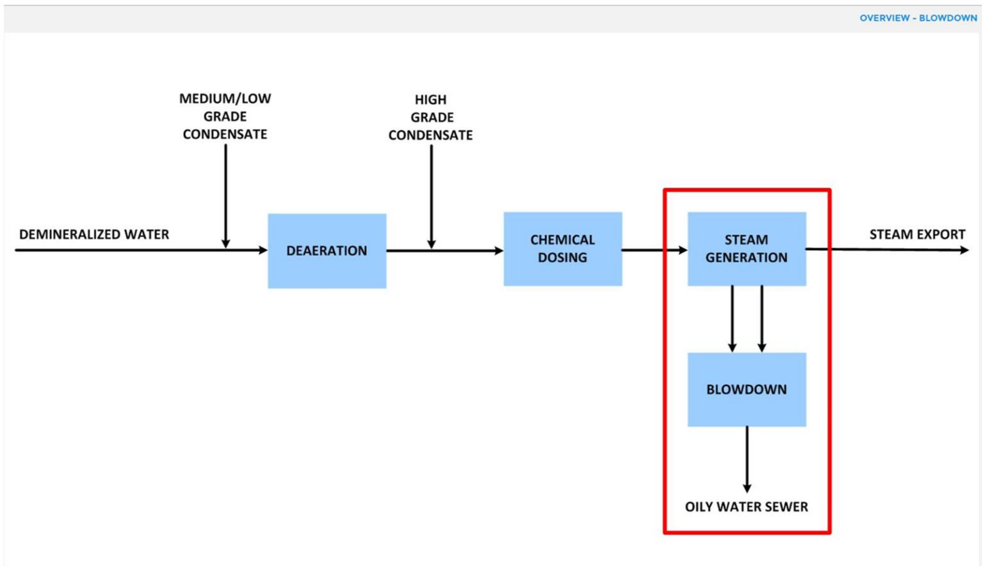
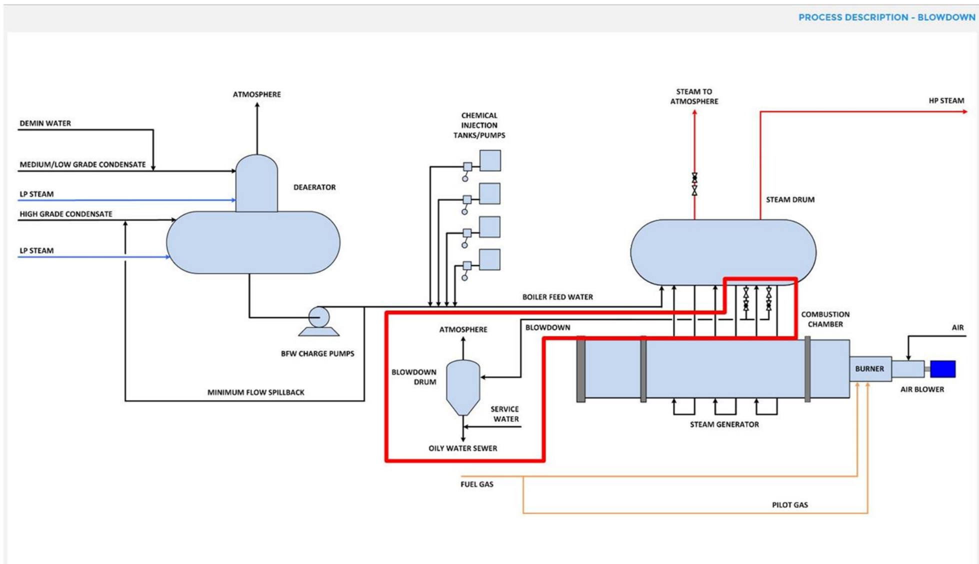


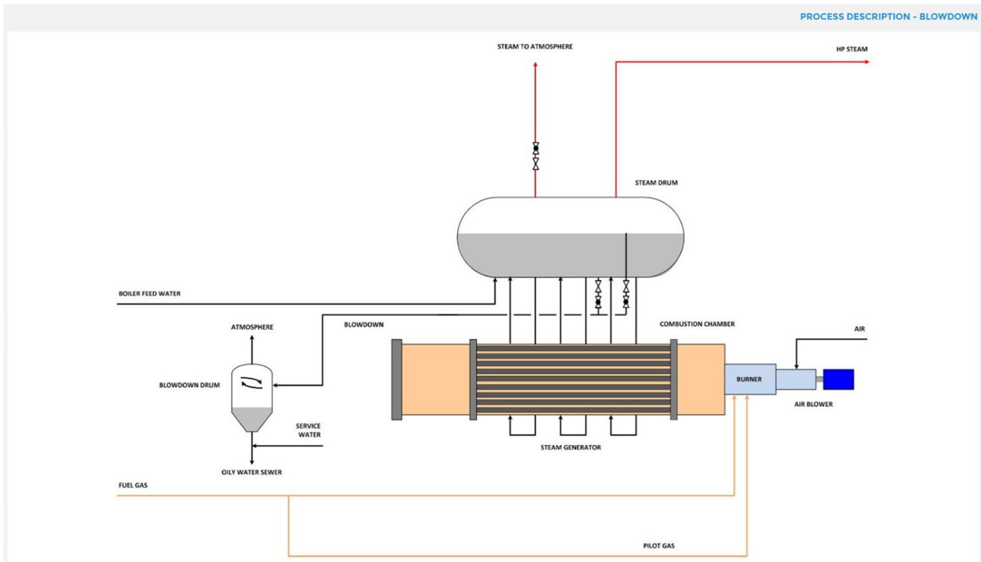
Our third topic is Blowdown.



Blowdown is the practice of removing accumulated contaminants from steam generation equipment by purging them to the oily water sewer.



There are two blowdown lines (intermittent and continuous) that draw boiler water from the steam drum.

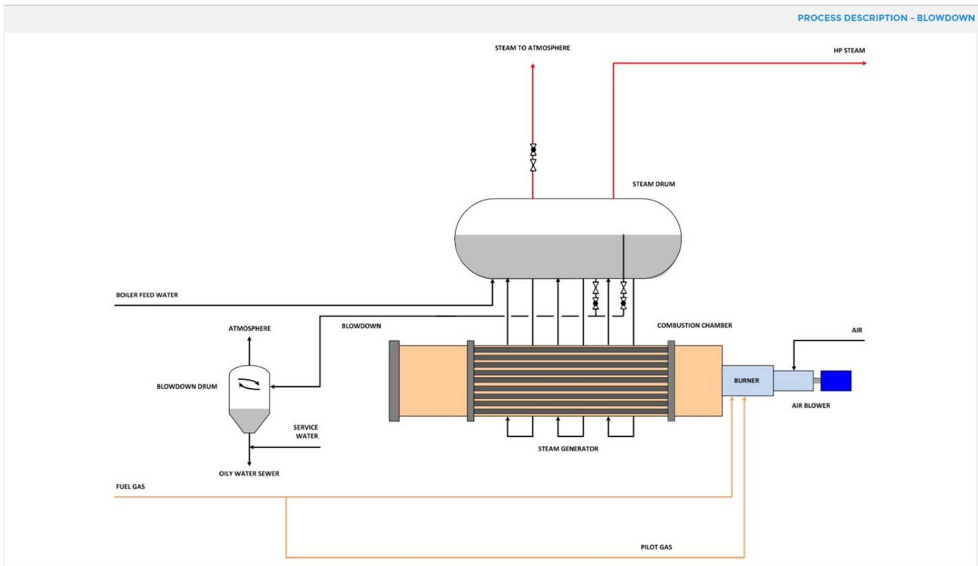


Intermittent blowdown

The purpose of the intermittent blowdown is to remove undissolved (or suspended) solids from a steam drum.

Although these solids tend to be dispersed throughout the water, the greatest concentration occurs at low points - which is where they’re drained from.

The quantity and frequency of intermittent blowdown depends on the quality of the boiler feed water and may range from zero to a short period each day.



Continuous blowdown

As steam is generated and withdrawn, most of the impurities in the boiler water remain behind.

These impurities consist of dissolved solids and some suspended solids, left over from chemical addition.

The water in the boiler therefore becomes highly concentrated in regard to these impurities and this concentration steadily rises as long as steam is being produced and drawn off.

If this concentration is not reduced by blowing down, then foaming and carry-over of impurities with the steam occurs, as well as the formation of sludge deposits within the boiler.

Continuous blowdown is the removal of the dissolved solids portion of these impurities.

Since steam separates from water in the steam drum, it is reasonable to assume that this is the region where dissolved solids will concentrate.

A narrow zone of water just below the normal operating level is the region of highest concentration.

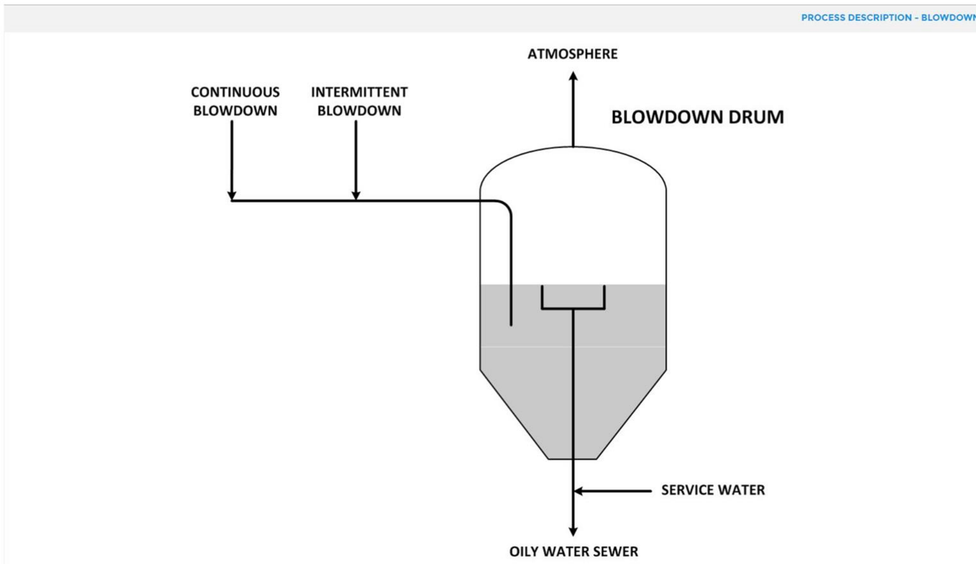
At this location a long collection tube, with inlet holes, runs inside the steam drum along its length.

This tube is connected by external piping to a blowdown drum, so that boiler water with a high level of total dissolved solids (TDS) can be safely removed.

The continuous blowdown rate depends on the TDS level in the boiler water which must be routinely analyzed and the continuous blowdown valve adjusted as necessary.

On steam generation systems using demineralized water, the continuous blowdown may be almost or completely closed under normal operation.

On others, it is typical to have a continuous blowdown flow rate equal to 1% or more of the generated steam flow.



Blowdown Drum

Blowdown involves hot, high pressure water. When this water is reduced to atmospheric pressure, it partially vaporizes.

The combination of pressure, vaporization and high temperature could cause extensive damage to sewer piping if the blowdown were to enter the sewer directly from the boiler.

To prevent this, the blowdown lines are routed through a blowdown drum before entering the sewer piping.

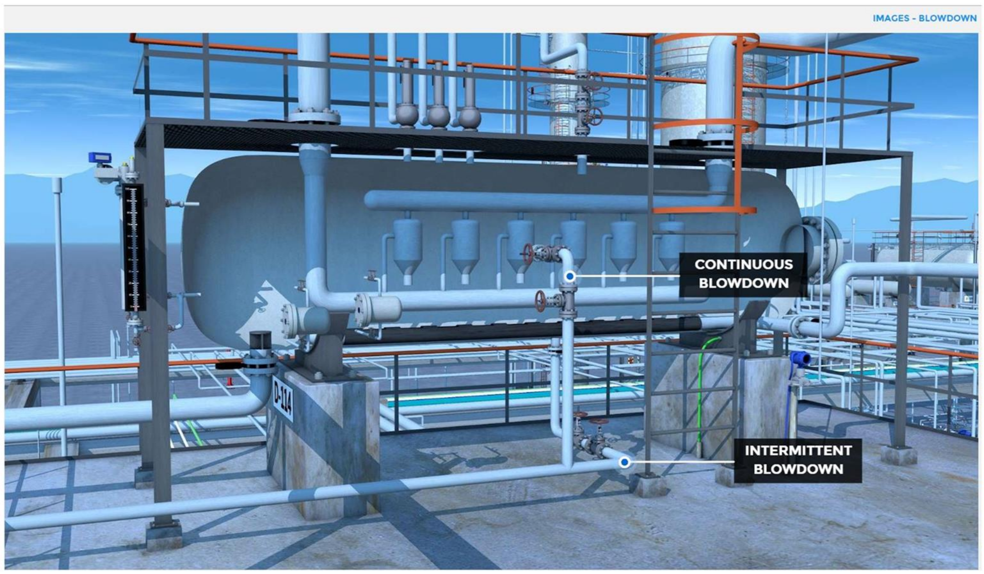
The blowdown drum provides a space for flash vapors to separate and vent and for the water to cool.

The inlet line from the boilers is positioned beneath the water level so that incoming hot water is submerged in the cooler drum water.

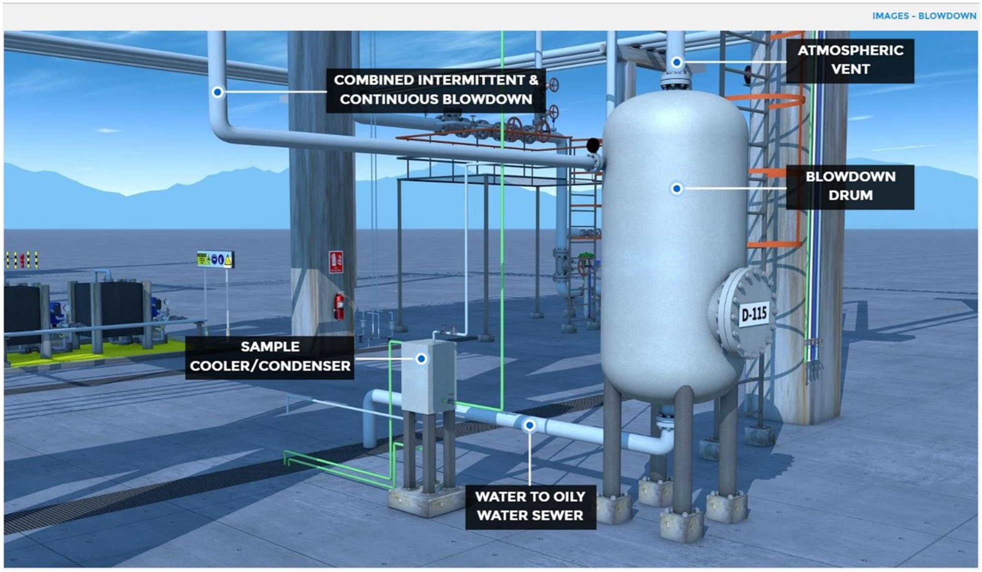
This also agitates the water in the drum so that sludge is kept dispersed.

As blowdown water enters, the drum overflows to the sewer, carrying the sludge along with the water.

Some plants may flush the sewer with cold service water just to be sure sewer damage doesn’t occur.

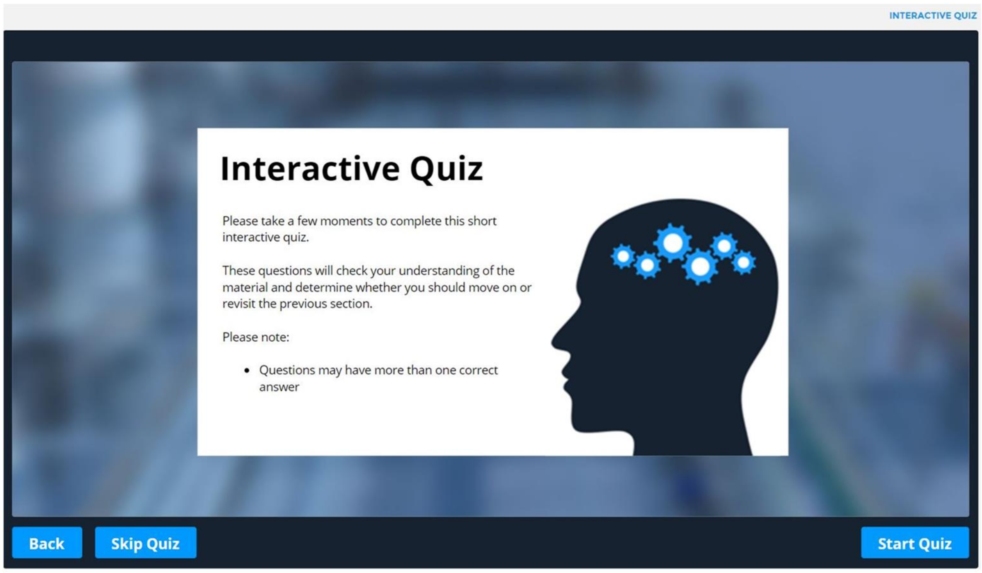


These 3D images show a high pressure steam drum intermittent blowdown (drawn from the bottom) and a continuous blowdown (drawn from just below the water surface).



And this image shows a typical blowdown drum.

There is a sample point with a cooler/condenser for drawing samples of blowdown water for testing in the laboratory.



Please take a few moments to complete this short interactive quiz and then click on the ‘next’ button below when you’re ready to move on.

To summarize:

To prepare high quality boiler feed water for steam generation from demineralized water and recycled condensate streams and maintain boiler water quality, the following key steps are required:

Deaeration:

To remove dissolved gases such as oxygen (O_2), carbon dioxide (CO_2) and sometimes ammonia (NH_3)

Chemical Dosing:

To scavenge for traces of oxygen

To disperse additive chemicals throughout the boiler feed water

To prevent foaming and priming

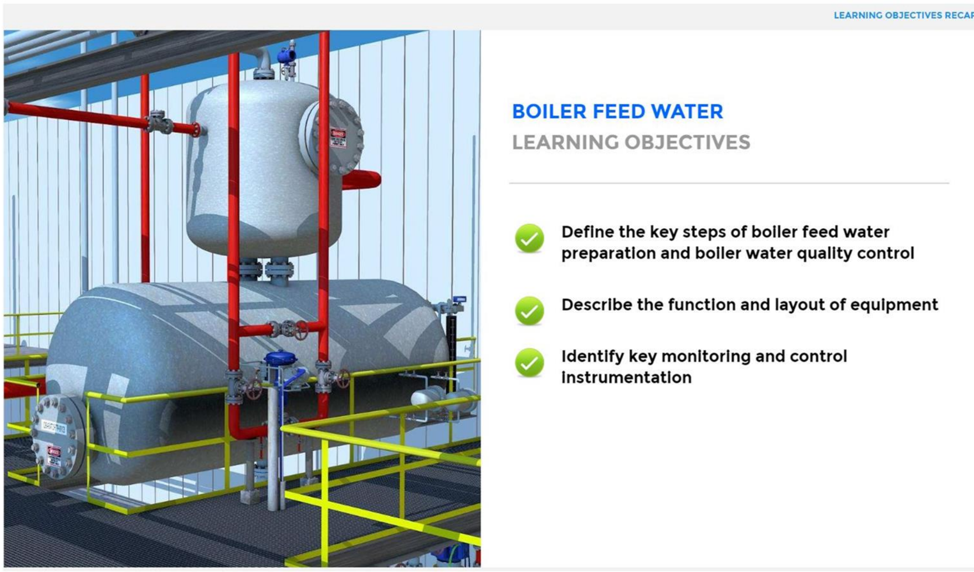
To reduce hardness

To maintain the pH

Blowdown:

Intermittent - to remove undissolved solids

Continuous - to remove dissolved solids



And that completes this module. Let's briefly recap your learning objectives.

By now, for boiler feed water preparation and boiler water quality control, you should be able to:

Define the key steps of boiler feed water preparation and boiler water quality control

Describe the function and layout of equipment

Identify key monitoring and control instrumentation

You can now close this module.