World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Review Article)

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The importance of boiler feed water and its treatment in a chemical plant

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World Journal of Advanced Research and Reviews, 2025, 27(01), 1624-1632

Publication history: Received on 10 June 2025; revised on 15 July 2025; accepted on 17 July 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.27.1.2705

Abstract

Water has a higher heat capacity than most other substances. This quality makes it an ideal raw material for boiler operations. Boilers are part of a closed system as compared to open systems in a gas turbine. This means that the water is recirculated throughout the system and is never in contact with the atmosphere. The water is reused and needs to be treated to continue efficient operations. Boiler water must be treated in order to be proficient in producing steam. Boiler water is treated to prevent scaling, corrosion, foaming, and priming. Boiler feedwater is an essential part of boiler operations. The feed water is put into the steam drum from a feed pump. In the steam drum the feed water is then turned into steam from the heat. After the steam is used, it is then dumped to the main condenser. From the condenser, it is then pumped to the deaerated feed tank. From this tank it then goes back to the steam drum to complete its cycle. The feedwater is never open to the atmosphere. This cycle is known as a closed system or Rankine cycle. Boiler water treatment is used to control alkalinity, prevent scaling, correct pH, and to control conductivity. The boiler water needs to be alkaline and not acidic, so that it does not ruin the tubes. There can be too much conductivity in the feed water when there are too many dissolved solids. These correct treatments can be controlled by efficient operator and use of treatment chemicals. The main objectives to treat and condition boiler water is to exchange heat without scaling, protect against scaling, and produce high quality steam.

Keywords: Boiler; Water; Turbine; Steam; Condenser

1. Introduction

A boiler is a class of vessel used to transform water under pressure into steam by application of heat. In the boiler furnace, the chemical energy in the fuel is converted into heat. The function of the boiler is to efficiently transfer heat to the contained water. The volume of water increases up to 1600 times as it boils, which is sufficient to cause explosion (Shokre, 2023).

Boiler feed-water is an essential part of boiler operations. The feed water is put into the steam drum from a feed pump. In the steam drum the feed water is then turned into steam from the heat. After the steam is used, it is then dumped to the main condenser. From the condenser, it is then pumped to the deaerated feed tank. From this tank it then goes back to the steam drum to complete its cycle. The feed-water is never open to the atmosphere. This cycle is known as a closed system or Rankine cycle (Mischissin, 2012).

During the early development of boilers, water treatment was not so much of an issue, as temperatures and pressures were so low that high amounts of scale and rust would not form to such a significant extent, especially if the boiler was "blown down". It was general practice to install zinc plates and/or alkaline chemicals to reduce corrosion within the boiler. Many tests had been performed to determine the cause (and possible protection) from corrosion in boilers using distilled water, various chemicals, and sacrificial metals. Silver nitrate can be added to feed-water samples to detect contamination by seawater. Use of lime for alkalinity control was mentioned as early as 1900, and was used by the

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French and British Navies until about 1935 (Shokre, 2023). In modern boilers, treatment of feed-water is critical, as problems result from using untreated water in extreme pressure and temperature environments. This includes lower efficiency in terms of heat transfer, overheating, damage, and costly cleaning.

1.1. Characteristics of boiler feed-water

Water has a higher heat capacity than most other substances. This quality makes it an ideal raw material for boiler operations. Boilers are part of a closed system as compared to open systems in a gas turbine. The closed system that is used is the Rankine cycle. This means that the water is recirculated throughout the system and is never in contact with the atmosphere. The water is reused and needs to be treated to continue efficient operations. Boiler water must be treated in order to be proficient in producing steam. Boiler water is treated to prevent scaling, corrosion, foaming, and priming. Chemicals are put into boiler water through the chemical feed tank to keep the water within chemical range. These chemicals are mostly oxygen scavengers and phosphates (Sendelbach, 2018). The boiler water also has frequent blowdowns in order to keep the chloride content down. The boiler operations also include bottom blows in order to get rid of solids. Scale is precipitated impurities out of the water and then forms on heat transfer surfaces. This is a problem because scale does not transfer heat very well and causes the tubes to fail by getting too hot. Corrosion is caused by oxygen in the water. The oxygen causes the metal to oxidize which lowers the melting point of the metal. Foaming and priming are used when the boiler water does not have the correct amount of chemicals and there are suspended solids in the water which carry over in the dry pipe (Shokre, 2023). The dry pipe is where the steam and water mixtures are separated.

1.2. Boiler feedwater treatment

Boiler water treatment is used to control alkalinity, prevent scaling, correct pH, and to control conductivity. The boiler water needs to be alkaline and not acidic, so that it does not ruin the tubes. There can be too much conductivity in the feed water when there are too many dissolved solids. These correct treatments can be controlled by efficient operator and use of treatment chemicals. The main objectives to treat and condition boiler water is to exchange heat without scaling, protect against scaling, and produce high quality steam. The treatment of boiler water can be put into two parts. These are internal treatment and external treatment. (Sendelbach, 2016) The internal treatment is for boiler feed water and external treatment is for make-up feed water and the condensate part of the system. Internal treatment protects against feed water hardness by preventing precipitating of scale on the boiler tubes. This treatment also protects against concentrations of dissolved and suspended solids in the feed water without priming or foaming. These treatment chemicals also help with the alkalinity of the feed water making it more of a base to help protect against boiler corrosion. The correct alkalinity is protected by adding phosphates. These phosphates precipitate the solids to the bottom of the boiler drum. At the bottom of the boiler drum there is a bottom blow to remove these solids. These chemicals also include anti-scaling agents, oxygen scavengers, and anti-foaming agents. Sludge can also be treated by two approaches. These are by coagulation and dispersion. When there is a high amount of sludge content it is better to coagulate the sludge to form large particles in order to just use the bottom blow to remove them from the feed water. When there is a low amount of sludge content it is better to use dispersants because it disperses the sludge throughout the feed water so sludge does not form (Bane, 2006).

1.3. Deaeration of feed water

Oxygen and carbon dioxide are removed from the feed water by deaeration. Deaeration can be accomplished by using deaerator heaters, vacuum deaerators, mechanical pumps, and steam-jet ejectors. In deaerating heaters, steam sprays incoming feed water and carries away the dissolved gases. The deaerators also store hot feed water which is ready to be used in the boiler. This means of mechanical deaeration is used with chemical oxygen scavenging agents to increase efficiency (Sendelbach, 2016). Deaerating heaters can be classified in two groups: spray types and tray types. With tray type heaters the incoming water is sprayed into steam atmosphere to reach saturation temperature. When the saturation temperature is reached most of the oxygen and non-condensable gases are released. There are seals that prevent the recontamination of the water in the spray section. The water then falls to the storage tank below. The non-condensables and oxygen are then vented to the atmosphere. The components of the tray type deaerating heater are a shell, spray nozzles, a direct contact vent condenser, tray stacks, and protective interchamber walls. The spray type deaerator is similar to the tray type deaerator. The water is sprayed into a steam atmosphere and most of the oxygen and non-condensables are released to the steam. The water then falls to the steam scrubber where the slight pressure loss causes the water to flash a little bit which also aids the removal of oxygen and non-condensables. The water then overflows to the storage tank. The gases are then vented to the atmosphere. With vacuum deaeration a vacuum is applied to the system and water is then brought to its saturation temperature. The water is sprayed into the tank like the spray and tray deaerators. The oxygen and non-condensables are vented to the atmosphere. (Sendelbach, 2016).

The feed-water must be specially treated to avoid problems in the boiler and downstream systems. Untreated boiler feed water can cause corrosion and fouling.

2. Boiler corrosion

Corrosive compounds, especially O_2 and CO_2 must be removed, usually by use of a deaerator. Residual amounts can be removed chemically, by use of oxygen scavengers. Additionally, feed water is typically alkalized to a pH of 9.0 or higher, to reduce oxidation and to support the formation of a stable layer of magnetite on the water-side surface of the boiler, protecting the material underneath from further corrosion. This is usually done by dosing alkaline agents into the feed water, such as sodium hydroxide (caustic soda) or ammonia. Corrosion in boilers is due to the presence of dissolved oxygen, dissolved carbon dioxide, or dissolved salts (Shun'an *et al.,* 2008).

2.1. Fouling

Fouling is the deposition of material on the heat transfer surface which reduces the film heat transfer coefficient. The impact of fouling on the heat exchanger is manifested as the reduction of thermal and hydraulic performance, in which the latter has a minor effect. (Rehman *et al* 2022).

Moreover, Fouling refers to the undesirable accumulation of material on surfaces, often in industrial equipment like heat exchangers or pipes. This buildup can reduce efficiency, increase costs, and even lead to equipment failure. Fouling can be caused by various substances, including scale, algae, debris, dissolved metals, and biological matter.

Deposits reduce the heat transfer in the boiler, reduce the flow rate and eventually block boiler tubes. Any non-volatile salts and minerals that will remain when the feed-water is evaporated must be removed, because they will become concentrated in the liquid phase and require excessive "blow-down" (draining) to prevent the formation of solid precipitates. Even worse are minerals that form scale (Shun'an *et al.,* 2008). Therefore, the make-up water added to replace any losses of feed-water must be demineralized/deionized water, unless a purge valve is used to remove dissolved minerals.

There are different types of fouling, namely: particulate fouling, Chemical reaction fouling, Corrosion fouling, Biofouling, crystallization fouling and precipitation fouling (Rehman *et al* 2022).

2.2. Locomotive boilers

A locomotive boiler is a specialized type of boiler designed to generate high-pressure steam, primarily for powering steam locomotives. It's a fire-tube boiler with a horizontal cylindrical shell containing tubes through which hot gases from the firebox pass, heating the surrounding water and producing steam (Wikipedia, 2025).

Steam locomotives usually do not have condensers so the feed-water is not recycled and water consumption is high. The use of deionized water would be prohibitively expensive so other types of water treatment are used. Chemicals employed typically include sodium carbonate, sodium bisulfite, tannin, phosphate and an anti-foaming agent (Sendelbach, 2016).

2.2.1. Why treat boiler water?

Boiler water treatment is essential for ensuring the safe, efficient, and long-lasting operation of boiler systems by preventing issues like scale, corrosion, and carryover. Treating boiler water helps maintain optimal performance, prevents costly downtime, and extends the equipment's lifespan (Wikipedia, 2025). Complete pure water is not achievable, impurities in boiler water include dissolved solids, dissolved gases and suspended matter.

2.2.2. Major problems associated with boiler feed water

Major problems associated with boiler feed water include corrosion, scale formation, foaming, carryover, and sludge accumulation. These issues arise from impurities in the water and can lead to decreased efficiency, equipment damage, and costly repairs. Thus, scaling/deposition, corrosion – oxygen attack, caustic corrosion, boiler water carryover, wasted fuel due to scale may be approximately 2-5%. However, water tube boilers experience heat flux rates as high as 250,000Btu/hr./ft^2

2.2.3. Common impurities in raw water

Common impurities in raw water include physical contaminants like suspended solids (e.g., silt, clay, and rust), chemical contaminants like dissolved minerals (e.g., calcium, magnesium, iron), and biological contaminants such as bacteria, viruses, and parasites. These impurities can originate from various sources, including soil erosion, industrial and agricultural runoff, and natural mineral deposits (Wikipedia, 2025). Examples of the impurities are:

- Dissolved solids – These are substances that will dissolve in water, carbonate and sulphates of calcium and magnesium, which are scale forming when heater. There are other dissolved solids which are non-scale forming.
- Suspended solids – These are substances that exist in water as suspended particles. They are usually minerals or organic in origin. These are not a problem as they can be filtered.
- Dissolved gases – Oxygen and carbon dioxide can be readily dissolved in water. These gases are aggressive instigators of corrosion.
- Scum forming substances – These are mineral impurities that foam and scum, e.g. soda in form of carbonate, chloride and sulphate.

2.3. Hardness

Water hardness refers to the concentration of dissolved minerals, primarily calcium and magnesium, in water. It's a measure of how much soap is needed to create a lather and how effectively soaps and detergents clean. Hard water can also cause mineral buildup in pipes and appliances (Wikipedia, 2025). Hard water contains scale forming impurities while soft water contains little or none.

2.3.1. There are two types of hardness

Alkaline harness (also known as temporary hardness) Calcium and Magnesium carbonates are responsible for this type of hardness. These salts dissolve in water to form an alkaline solution. When heat is applied, they decompose to release carbon dioxide and soft scale or sludge. Their harness is removable by boiling while non-alkaline harness and carbonates (also known as permanent hardness) calcium and Magnesium but in the form of sulphate and chlorides. These precipitate out of solution due to their reduced solubility as temperature rises and form hard scales which are difficult to remove. The presence of silica can also lead to hard scale, which can react with calcium and magnesium scales to form silicates, which can severely inhibit heat transfer and cause overheating (Wikipedia, 2024).

Total hardness in water refers to the total concentration of dissolved divalent metal cations, primarily calcium and magnesium, expressed as equivalent calcium carbonate ($CaCO3$). It essentially indicates the "hardness" or mineral content of the water. Total hardness is the sum of concentrations of calcium and Magnesium ions present when these are expressed as $CaCO_3$

2.4. pH

A numerical value representing a potential hydrogen content of water –which is a measure of the acidic or alkaline nature of the water. Alkalinity is a measure of the capacity of water to neutralize acids. Alkalinity of water is due primarily to the presence of Bicarbonate, carbonate and hydroxide ions. Salts of weak acids such as Borates may also contribute. Carbonate alkalinity is a measure of the carbonate and bicarbonate ions in a solution (Wikipedia, 2024).

2.5. Oxygen corrosion prevention in steam generation system

Oxygen corrosion in steam generation systems is primarily mitigated through a combination of mechanical and chemical methods. Mechanical methods involve deaeration to remove dissolved oxygen, while chemical methods utilize oxygen scavengers and corrosion inhibitors to further reduce oxygen levels and protect metal surfaces (Wikipedia, 2024).

Oxygen in addition of being dissolved in feed water may enter a steam generator combined with corrosion products such as ferric oxide ($Fe2O3$), copper oxide (CuO) etc. Oxidized Iron for example is not removed by deaeration and may cause corrosion in high heat transfer areas of the steam generation.

$$4Fe2O3 + Fe \rightarrow 3Fe3O4 \quad \text{............Equation 1}$$

Iron is taken from the coil metal as $Fe2O3$ is reduced to magnetic Iron oxide ($Fe3O4$). Hydrazine can minimize this type of attack by reacting with and reducing these oxidized corrosion products.

$$N_2H_4 + 6Fe_2O_3 \rightarrow 4Fe_3O_4 + N_2 + 2H_2O \quad \text{………….Equation 2}$$

Oxygen is then directly removed by the magnetic Iron oxide formed as shown

$$4Fe_3O_4 + O_2 \rightarrow Fe_2O_3 \quad \text{………… Equation 3}$$

In practice high initial dosage of hydrazine are needed before a residual is established. This tends to confirm that Hydrazine is used up by first reacting with oxidized corrosion products. The starting dosage for Hydrazine is usually absent twice the amount needed to react with oxygen.

Carbonate alkalinity in the steam generator can hydrolyze under the action of heat and liberate carbon dioxide which will be carried along with the steam to form a corrosive carbonic acid product with the condensate in process heat exchanger or condensate piping. Ammonia has been successfully employed for neutralization of carbon dioxide and elevation of pH. It is anticipated that not more than 0.2 to 0.3 ppm of ammonia will be required to maintain the desired pH range (Lyon *et al.,* 2012).

2.6. Scale

A scale inhibitor is a chemical treatment used to prevent or reduce the formation of mineral scale deposits on surfaces in contact with water or other fluids, particularly in industrial and oilfield applications. These chemicals work by interfering with the crystal growth of scale-forming minerals, preventing them from adhering to surfaces and causing blockages or reduced flow (Wikipedia, 2024).

The primary cause of scale formation is the fact that the solubility of the scale-forming salts decreases with an increase in temperature. The higher the operating temperature (and pressure) in a steam generator the more insoluble the incrusting salts become. The chief mechanism of scale formation is due to the crystallization of scale forming salts from the solution, locally supersaturated.

Crystallization of scale results directly on the heating surface even when the solubility of the scale forming salts has not been exceeded in the steam generator water. At boiling temperatures, calcium and Magnesium bicarbonates decompose to their respective carbonates and carbon dioxide being produced in the reaction. The solubility of most calcium and magnesium salts decrease with increase in temperature. These salts are collectively termed "Hardness" Magnesium sulphate is the exception, but it usually reacts in steam generator water to form less soluble Magnesium salts. Calcium sulphate, at higher temperatures decrease in solubility and tends to deposit out in the hotter parts of the steam generator where scale can cause the most damage (Wikipedia, 2024).

In general, all hardness salts are potential scale formers, since they deposit out of solution as water is heated. The solubility of sodium increases as water is heated and does not normally cause steam generator deposits. Should a higher deposit of sodium be found in a steam generator deposit, it indicates an unusual condition such as where water is evaporated to virtual dryness.

Scale may form other items such as silica or products from silica may deposit out as calcium silicate and prove to be quite troublesome in steam generator operation. Maintenance of high alkalinity concentration in steam generator water is an aid in control of this problem; however, only limited silica concentrations can be controlled. Soluble iron entering a steam generator with the feed water will be precipitated by a steam generator water pH of 10 or more and consequently this pH range is generally maintained in a high-pressure steam generator.

The different types of scale formed, all possess a low degree of heat conductivity. The presence of scale is therefore equivalent to spreading a thin film of insulation across the path of heat travel from the hot gases to the steam generator water. This heat insulating material will retard heat transfer and cause a loss of steam generator efficiency.

Even more important than the effect of scale in causing heat loss, however is the effect of scale causing the overheating of boiler metal and subsequent tube failure (Wikipedia, 2024).

3. Treatment

To prevent scale formation in steam generators, a multi-faceted approach is crucial, encompassing water treatment, chemical conditioning, and proper maintenance practices. This includes using water softeners, chemical treatments like oxygen scavengers and scale inhibitors, and regular blowdown to remove accumulated solids (Wikipedia, 2024).

Treatment to prevent steam generator scale is needed in every scale. Even though the feed water hardness is less than 1ppm, treatment is usually required. One ppm of feed water hardness (or Iron) slipping through a softener adds up to about 200kg of potential scale a year, in a steam generator making 50,000lbs/hr (20,000kg/hr) (Lyon *et al.,* 2012).

Treatment involves

- Controlling hardness precipitation – reaction should occur in the cooler area of the steam generator drum at or near the feed water entrance. The hardness should come out of solution and be suspended in the water rather than depositing out directly on steam generator metal
- Conditioning steam generator water suspended solids or sludge.
- The sludge must be properly treated before passing to the hot steam generator area to keep it from sticking to the tubes.
- The excess sludge must be removed by blowdown. This is done by intermittent blowdown at the low point in the steam release area in the steam generator drum.

3.1. Steam contamination

Steam contamination refers to the presence of unwanted substances in steam, compromising its purity and potentially impacting its intended use in various applications like power generation, chemical processing, and food production. This contamination can introduce solids, liquids, or gases into the steam, affecting its quality and leading to various issues in the systems where it's used (Wikipedia, 2024). Steam contamination may occur when steam generator reacts in any one of the following ways: Foams, Primes or during carryover

3.2. Foaming

Foaming is the condition resulting from the formation of bubbles on the surface of the steam generator water. The foam produced may entirely fill the steam space of it may be of relatively minor depth. In either case, this foaming condition causes appreciable entrainment of water with the steam. It should be pointed out that demisting pad and other mechanical equipment are used to prevent the release of wet steam to the system. Regardless of mechanical provision, steam generator water should be maintained as pure as possible to contain foaming (Sendelbach, 2016).

3.3. Priming

Priming is a more violent and spasmodic action resulting in the throwing of slugs of steam generator water over with the steam. This condition can exist because of high water level, broken baffling, a sudden drastic increase in steam load and a sudden or severe contamination of steam generator water (Wikipedia, 2024).

Very often a combination of several of these conditions contributes to priming.

3.4. Carryover

Carryover is the term applied to the continuous entrainment of relatively small quantity of steam generator water solids with the steam. The term carryover is also used to cover the general conditions more exactly divided into foaming, priming and carryover.

When steam generator water solids are carried over in the steam (such as silica) deposits will occur in non-return and stop valves, super heaters, steam piping and turbines. Such deposits can promote failure of super heater tubes and loss in turbine efficiency (Sendelbach, 2016).

3.4.1. Silica carryover

One of the most common types of carryovers is silica carryover. The key to minimizing silica carryover is to maintain silica content of the steam generator below 3.5ppm when at an operating pressure of 105.5kgcm^{-2} (1,500psig). The dissolved silica in the steam production under normal operating conditions would be not more than 0.02ppm. With a steam silica content of 0.02ppm or less as determined empirically by turbine experts and utilities operators, appreciable turbine deposits would not occur. Thus, this content is a practical maximum limit

3.5. Coordinated phosphate treatment

Coordinated phosphate treatment in boiler systems aims to control water chemistry to prevent corrosion and scale formation. It involves maintaining a specific ratio of phosphate to hydroxide (or alkalinity) in the boiler water, typically using a combination of di-sodium phosphate and tri-sodium phosphate. This approach helps to manage the pH and prevent the formation of free caustic, which can lead to corrosion (Wikipedia, 2024).

In the phosphate treatment, a small quantity of caustic is added to the steam generator to maintain it in an alkaline state, but avoiding the presence of excessive free hydroxide. At 5% solution of di/tri-sodium phosphate is injected intermittently or continuously into the steam generator drum as required to maintain a small phosphate residual of 10-20ppm.

The primary purpose of phosphate addition to the water is to precipitate the hardness constituents under the proper pH conditions of between 9.5 and 10. The coordinated phosphate treatment is not generally used in steam generators operating above 112.5kgcm^{-2}

3.6. Coordinated phosphate curve

A "coordinated phosphate curve" typically refers to a control method used in power generation boilers to manage phosphate levels and prevent corrosion and scale formation. It involves maintaining a specific ratio of sodium to phosphate in the boiler water, typically using a mixture of trisodium phosphate (Na3PO4) and disodium phosphate (Na2HPO4). This approach helps maintain a desired pH level and minimize the risk of caustic attack on boiler components (Wikipedia, 2024).

However, coordinated phosphate control for control in the moderately high pressure steam generators operation should be on or below the curve to prevent free caustic in the steam generator. If operating above the curve as traces of impurities enter the cycle with the make-up water, the phosphate will be precipitated producing free hydroxide. The free hydroxide can be controlled by adding di-sodium phosphate (Shun'an *et al.,* 2008). Generally, free hydroxide should be maintained within 0 – 1ppm

4. Solid accumulation

"Solid accumulation" generally refers to the buildup or collection of solid materials over time. This could refer to various things, including waste accumulation, sediment accumulation in a natural environment, or the accumulation of solids in industrial processes. The context of "solid accumulation" is important to understand its specific meaning (Wikipedia, 2024).

If suspended solids (sludge) and dissolved solids are allowed to accumulate because of low blowdown rate, the possibility of sludge deposits and carryover in the steam is enhanced. During start up periods, suspended Iron might be high in relation to total solids and blowdown might be partly or entirely based on Iron concentration. High suspended Iron in steam generator water can produce serious deposit problems.

The importance of frequent intermittent high-rate blowdown during both the initial and subsequent startups should be emphasized to ensure as complete a removal of solids as possible in a minimum period of time. If the steam generator water is visibly dirty at the blowdown after heating is started, the blowdown frequency should be about twice an hour for a duration of one to two minutes at each blowdown point. When the water appearance is about normal, samples should be analyzed for total dissolved solids, Iron and silica. There will be frequent periods of two- or three-hours duration, such as during regeneration of the demineralizer unit, that a slight increase of solids will be present in the steam generator feed water. This slight increase of solids may be compensated for by phosphate injection and slightly increased blowdown.

5. Phosphate hideout

Phosphate hideout is a phenomenon in boilers where phosphate compounds, used for water treatment, precipitate out of solution under high heat and pressure, only to redissolve when conditions change, potentially leading to corrosion and control issues (Wikipedia, 2024).

Phosphate hideout is not usually encountered in the operation 105-kgcm^{-2} steam generators, but will probably be evident to some degree. It is the term used to express the phenomenon of the partial disappearance of phosphate in the steam generator water upon increase in load and its reappearance upon load reduction

The term is used where the hideout is greater than 5ppm change between high load and low load. High pressure steam generator operation, phosphate residual levels are maintained at a low-level range to avoid appreciable phosphate hideout. A precise blowdown schedule cannot be arrived at by water analysis alone. Inspection of system components for deposits and laboratory analysis of sampled deposits after a period of operation, and any remedial measures taken are required before attempting finalization of blowdown practice (Shokre, 2023).

Intermittent blowdown is not efficient at maintaining a consistent level of solids in the steam generator, so a continuous blowdown connection should be provided to minimize solid fluctuation in the steam generator water and to provide a more accurate control of the rate. This blowdown connection is usually located on the steam drum near the discharge from the generating tubes and away from the feed water inlet. An internal collector pipe is usually supplied for this nozzle.

Until the steam generator water purity approaches normal, the steam generator pressure should be limited to approximately 35.2kgcm^{-2} with minimum steam load. As steam generator water purity approaches normal the blow down frequency can be reduced accordingly and pressure can be gradually increased. Blowdown from furnace tubes should be stopped

Analysis of steam generator water samples should be made rather frequently since relatively wide fluctuations could conceivably occur in the quality of the water. Before hot gases are started to elements of steam generator system not yet in service, they should be thoroughly blown down to be sure they are free of any solid accumulation. The blowdown will also preheat those elements for operation (Bane, 2013). Once they are in service as a general rule, no heat receiving tube bundle should be blown down.

6. Conclusion

The expected steam quality of 50ppb is achieved by using a high purity feed water, an effective feed water treatment program, and by good control of the steam generator water composition in a well-designed system with proper and efficient operation supported by accurate sample analyses. Corrosive compounds, especially O2 and CO2 must be removed, usually by use of a deaerator. Residual amounts can be removed chemically, by use of oxygen scavengers. Additionally, feed water is typically alkalized to a pH of 9.0 or higher, to reduce oxidation and to support the formation of a stable layer of magnetite on the water-side surface of the boiler, protecting the material underneath from further corrosion. This is usually done by dosing alkaline agents into the feed water, such as sodium hydroxide (caustic soda) or ammonia. Corrosion in boilers is due to the presence of dissolved oxygen, dissolved carbon dioxide, or dissolved salts.

It is also essential that the steam generator be properly secured during short term out of service periods which could result from equipment malfunction or by startup delays. During these periods, the steam generator drum should be immediately blanketed with Nitrogen and a positive pressure of Nitrogen maintained until such time that the steam generator system is readied for steam production. In addition, small residual of O2 scavenger should be maintained.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict-of-interest to be disclosed.

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