BOILER SYSTEM CHEMICAL TREATMENT 101

The primary function of a boiler is to transfer heat from hot gases generated by the combustion of fuel into water until it becomes hot or turns to steam. The steam or hot water can then be used in building or facility processes. Boiler feedwater often contains impurities, which impairs boiler operation and efficiency. Chemical additives can be used to correct the problems caused by these impurities. To improve feedwater quality, and steam purity, these chemicals can be injected directly into the feedwater or steam.

Benefits of Chemical Treatments

- Increase boiler efficiency;
- Reduce fuel, operating and maintenance costs;
- Minimize maintenance and downtime; and
- Protect equipment from corrosion and extend equipment lifetime.

CHEMICAL TREATMENTS FOR WATERSIDE OF BOILER TUBES

The feedwater is composed of makeup water (usually city water from outside boiler room/ process) and condensate (condensed steam returning to the boiler). The feedwater normally contains impurities, which can cause deposits and other related problems inside the boiler. Common impurities in water include alkalinity, silica, iron, dissolved oxygen and calcium and magnesium (hardness). Blowdown, a periodic or continuous water removal process, is used to limit the concentration of impurities in boiler water and to control the buildup of dissolved solid levels in the boiler. Blowdown is essential in addition to chemical treatments.

List of Problems Caused By Impurities in Water

Impurity (Chemical Formula)	Problems	Common Chemical Treatment Methods
Alkalinity (HCO_3-, CO_3^{2-} and $CaCO_3$)	Carryover of feedwater into steam, produce CO_2 in steam leading to formation of carbonic acid (acid attack)	Neutralizing amines, filming amines, combination of both, and lime-soda.
Hardness (calcium and magnesium salts, $CaCO_3$)	Primary source of scale in heat exchange equipment	Lime softening, phosphate, chelates and polymers
Iron (Fe^{3+} and Fe^{2+})	Causes boiler and water line deposits	Phosphate, chelates and polymers
Oxygen (O_2)	Corrosion of water lines, boiler, return lines, heat exchanger equipments, etc. (oxygen attack)	Oxygen scavengers, filming amines and deaeration
pH	Corrosion occurs when pH drops below 8.5	pH can be lowered by addition of acids and increased by addition of alkalies
Hydrogen Sulfide (H_2S)	Corrosion	Chlorination
Silica (SiO_2)	Scale in boilers and cooling water systems	Lime softening

Boiler Waterside Fouling

Scale is one of the most common deposit related problems. Scale is a buildup of solid material from the reactions between the impurities in water and tube metal, on the water-side tube surface. Scale acts as an insulator that reduces heat transfer, causing a decrease in boiler efficiency and excessive fuel consumption. More serious effects are overheating of tubes and potential tube failure (equipment damage).

Oxygen Attack

Oxygen attack is the most common causes of corrosion inside boilers. Dissolved oxygen in feedwater can become very aggressive when heated and reacts with the boiler's internal surface to form corrosive components on the metal surface. Oxygen attack can cause further damage to steam drums, mud dams, boiler headers and condensate piping.

Acid Attack

Acid attack is another common cause of corrosion. Acid attack happens when the pH of feedwater drops below 8.5. The carbonate alkalinity in the water is converted to carbon dioxide gas (CO2) by the heat and pressure of the boilers. CO2 is carried over in the steam. When the steam condenses, CO2 dissolves in water to form carbonic acid (H2CO3) and reduces the pH of the condensate returning to the boilers. Acid attack may also impact condensate return piping throughout the facility.

BOILER SYSTEM CHEMICAL TREATMENTS AND FEED EQUIPMENT REQUIREMENTS

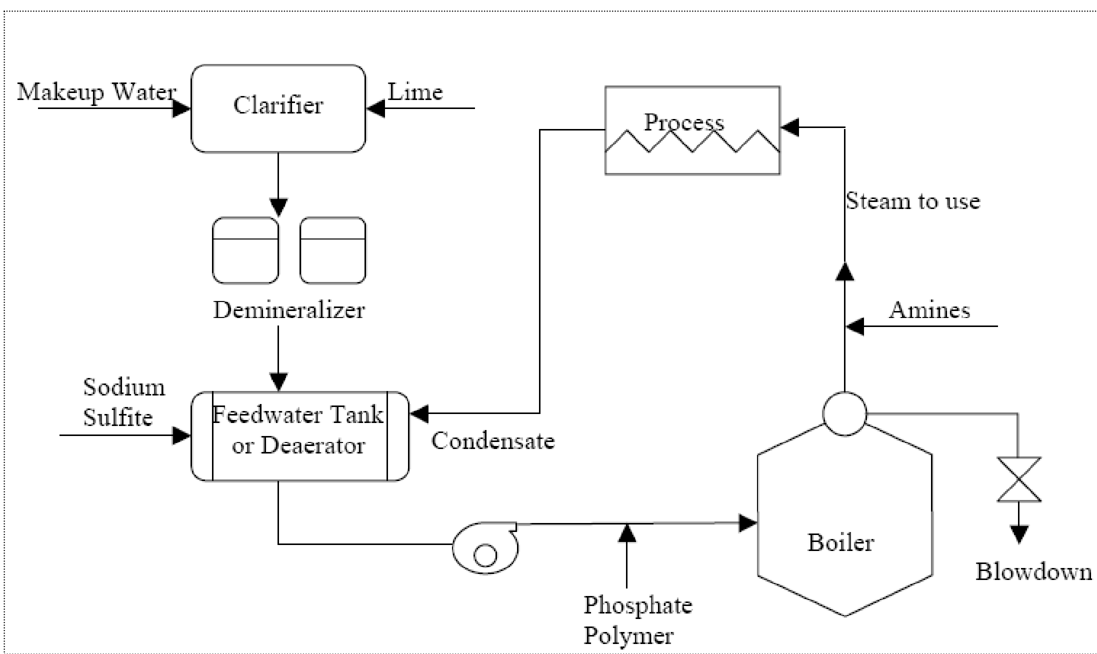
Product Feed Considerations

An often-overlooked fact is that the water treatment program usually represents a small percentage of the overall costs of a boiler operation. However, poor treatment or equipment performance can create domino effects increasing operating and maintenance costs.

For best results, all chemicals for internal treatment of a steam generating facility must be fed continuously and at proper injection points. Chemicals may be fed directly from the storage tank (neat) or may be diluted in a day tank with high-purity water. Certain chemicals may be mixed together and fed from the same day tank.

Chemical feed points are usually selected as far upstream in the boiler water circuit as possible. For chemical feed beyond the feedwater pump or into the steam drum, the pump must be matched to the boiler pressure. For high-pressure boilers, proper pump selection is critical.

Basic Boiler System Schematic



As shown in the figure, a steam generating system includes three major components for which treatment is required: the deaerator, the boiler, and the condensate system. Oxygen scavengers are usually fed to the storage section of the deaerator. The boiler internal treatment is fed to the feedwater pump suction or discharge, or to the steam drum. Condensate system feed points also vary, according to the chemical and the objective of treatment. Typical feed points include the steam header or other remote steam lines.

Chemical Treatments

Lime Softening and Soda Ash

Lime is added to hard water to precipitate the calcium, magnesium and, to some extent, the silica in the water. Soda ash is added to precipitate non-bicarbonate hardness. The process typically takes place in a clarifier followed by a hydrogen cycle cation exchange and a hydroxide cycle anion exchange demineralization.

Both hydrated lime and soda ash can be purchased as a liquid, a slurry or in a dry granular form. Specialized handling and preparation systems are required for dry storage and makedown.

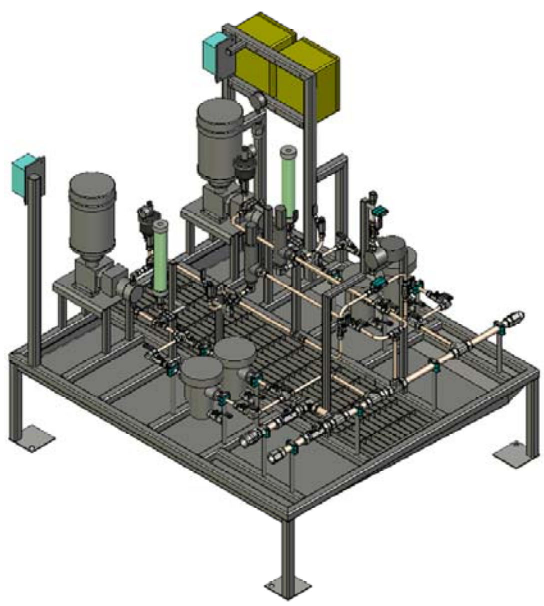
Oxygen Scavengers

A deaerator removes most of the oxygen in feedwater; however, trace amounts are still present and can cause corrosion-related problems. Oxygen scavengers are added to the feedwater, preferably in the storage tank of the feedwater, to remove the trace mount of oxygen escaped from the deaerator. The most commonly used oxygen scavenger is sodium sulfite. Sodium sulfite is cheap, effective and can be easily measured in water.

Sulfite (Oxygen Scavenger)

Uncatalyzed sodium sulfite may be mixed with other chemicals. The preferred location for sulfite injection is a point in the storage section of the deaerating heater where the sulfite will mix with the discharge from the deaerating section.

If sulfite is fed alone, the following basic equipment is needed:



- skid mounted dual metering pumps (duty/stand-by) with stainless steel wet end/trim
- pulsation dampener
- stainless steel relief valve
- stainless steel check valve
- stainless steel Y-strainer
- stainless steel tubing, valves, and fittings
- flowmeter
- calibration cylinder
- pressure gauge with diaphragm seals
- electrical junction boxes
- dilution water line c/w static mixer (optional)
- drip pan (optional)
- *In all cases, an injection quill should be used.*

Sulfite shipped as liquid concentrate is usually acidic and, when fed neat, corrodes stainless steel tanks at the liquid level. Sulfite storage tanks must be fiberglass, or polyethylene. Lines may be PVC or 316 stainless steel.

Catalyzed Sulfite (Oxygen Scavenger)

Catalyzed sulfite must be fed alone and continuously. Mixing of catalyzed sulfite with any other chemical impairs the catalyst. For the same reason, catalyzed sulfite must be diluted with only condensate or demineralized water. To protect the entire preboiler system, including any economizers, catalyzed sulfite should be fed to the storage section of the deaerating heater. Caustic soda may be used to adjust the pH of the day tank solution; therefore, a mild steel tank cannot be used. ***Materials of construction for feed equipment are the same as those required for regular sulfite.***

Hydrazine (Oxygen Scavenger)

Hydrazine is compatible with all boiler water treatment chemicals except organics, amines, and nitrates. However, it is good engineering practice to feed hydrazine alone. It is usually fed continuously into the storage section of the deaerating heater. Because of handling and exposure concerns associated with hydrazine, closed storage and feed systems have become standard. ***Materials of construction are the same as those specified for sulfite.***

Organic Oxygen Scavengers

Many organic compounds are available, including hydroquinone and ascorbic acid. Some are catalyzed. Most should be fed alone. Like sulfite, organic oxygen scavengers are usually fed continuously into the storage section of the deaerating heater. ***Materials of construction are the same as those specified for sulfite.***

Neutralizing Amines

Neutralizing amines are high pH chemicals that neutralize the carbonic acid formed in the condensate (acid attack). The three most commonly used neutralizing amines are morpholine, diethyleminoethanal (DEAE) and cyclohexylamine. Neutralizing amines cannot protect against oxygen attack; however, it helps keep oxygen less reactive by maintaining an alkaline pH.

Neutralizing amines may be fed to the storage section of the deaerating heater, directly to the boiler with the internal treatment chemicals, or into the main steam header. Some steam distribution systems may require more than one feed point to allow proper distribution. An injection quill is required for feeding into a steam distribution line.

Neutralizing amines are usually fed based on condensate system pH and measured corrosion rates. These amines may be fed neat, diluted with condensate or demineralized water, or mixed in low concentrations with the internal treatment chemicals. **A standard packaged pump skid and tank can be used for feeding.**

Filming Amines

Filming amines are various chemicals that form a protective layer on the condensate piping to protect it from both oxygen and acid attack. The two most common filming amines are octadecylamine (ODA) and ethoxylated soya amine (ESA). Combining neutralizing and filming amine is a successful alternative to protect against both acid and oxygen attack.

The filming amines should be continuously fed into steam headers at points that permit proper distribution. A single feed point is satisfactory for some systems. In every case, the steam distribution should be investigated and feed points established to ensure that all parts of the system receive proper treatment. Filming amines must be mixed with condensate or demineralized water. Water containing dissolved solids cannot be used, because the solids would contaminate the steam and could produce unstable amine emulsions.

The use of stainless steel tanks is recommended. **Equipment specifications are the same as those for regular sulfite, except that a vapor-type injection nozzle or quill is required**.

Internal Treatment Chemicals

There are three major classifications of chemicals used in internal treatment: phosphates, chelants, and polymers. These chemicals may be fed either separately or in combination; in most balanced treatment programs, two or three chemicals are fed together. The preferred feed point varies with the chemical specified. For example, when caustic soda is used to maintain boiler water alkalinity, it is fed directly to the boiler drum. When caustic is used to adjust the feedwater pH, it is normally injected into the storage section of the deaerating heater.

Phosphate

Mono-, di- or trisodium phosphate and sodium polyphosphate can be added to treat boiler feedwater. Phosphate buffers the water to minimize pH fluctuation. It also precipitates calcium or magnesium into a soft deposit rather than a hard scale. Additionally, it helps to promote the protective layer on boiler metal surfaces. However, phosphate forms sludge as it reacts with hardness; blowdown or other procedures should be established to remove the sludge during a routine boiler shutdown.

Phosphates are usually fed directly into the steam drum of the boiler, although they may be fed to the feedwater line under certain conditions. Treatments containing orthophosphate may produce calcium phosphate feed line deposits; therefore, they should not be fed through the boiler feed line. Orthophosphate should be fed directly to the boiler steam drum through a chemical feed line. Polyphosphates must not be fed to the boiler feedwater line when economizers, heat exchangers, or stage heaters are part of the preboiler system. If the preboiler system does not include such equipment, polyphosphates may be fed to the feedwater piping provided that total hardness does not exceed 2 ppm.

In all cases, feed rates are based on feedwater hardness levels. Phosphates should be fed neat or diluted with condensate or high-purity water. **Mild steel tanks, fittings, and feed lines are appropriate. If acidic phosphate solutions are fed, stainless steel is recommended.**

Chelants

Nitrilotriacetic acid (NTA) and ethylenediamine tetraacetic acid (EDTA) are the most commonly used chelants. Chelants combine with hardness in water to form soluble compounds. The compounds can then be eliminated by blowdown.

- Chelants treatment is not recommended for feedwater with high hardness concentration
- Chelants should not be fed if the feedwater contains a significant level of oxygen.
- Chelants should never be fed directly into a boiler

The preferred feed location for chelants is downstream of the feedwater pump. All chelant treatments must be fed to the boiler feedwater line by means of a stainless steel injection nozzle at a point beyond the discharge of the boiler feed pumps. If heat exchangers or stage heaters are present in the boiler feed line, the injection point should be at their discharge. Care should be exercised in the selection of metals for high-temperature injection quills.

At feed solution strength and elevated temperatures, chelating agents can corrode mild steel and copper alloys; therefore, 304 or 316 stainless steel is recommended for all feed equipment. **Equipment specifications are the same as those for regular sulfite.** Chelant products may be fed neat or diluted with condensate. Chelant feed rates must be carefully controlled based on feedwater hardness, because misapplication can have serious consequences.

Polymeric Dispersants. In most applications, polymeric dispersants are provided in a combined product formulation with chelants and/or phosphates. Dilution and feed recommendations for chelants should be followed for chelant-dispersant and chelant-phosphate-dispersant programs. Dilution and feed recommendations for phosphates should be followed for phosphate-dispersant programs. These combination programs typically have the best results with respect to boiler cleanliness.

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Computerized Boiler Chemical Feed Systems

Computerized boiler chemical feed systems are being used to improve program results and cut operating costs. These systems can be used to feed oxygen scavengers, amines, and internal treatment chemicals.

A typical system incorporates a metering pump, feed verification equipment, and a microprocessor-based controller. These systems are often linked to personal computers, which are used to monitor program results, feed rates, system status, and plant operating conditions. Trend graphs and management reports can then be produced to provide documentation of program results and help in troubleshooting.

In many cases, these systems can be programmed to feed boiler treatment chemicals according to complex customized algorithms. For example, chelant feed can be adjusted automatically, based on analyzer or operator hardness test results, boiler feedwater flow, and minimum/maximum allowable product feed rates. Thus, chemical feed precisely matches system demand, virtually eliminating the possibility of underfeed or overfeed.

Feed verification is another important facet of some computerized feed systems. The actual output of the pump is continuously measured and compared to a computer-calculated setpoint. If the output doesn't match the set point, the speed or stroke length is automatically adjusted. The benefits of this technology include the elimination of time-consuming drawdown measurements, the ability to feed most chemicals directly from bulk tanks, precise chemical residual control, and minimal manpower requirements.
