A Total Boiler System

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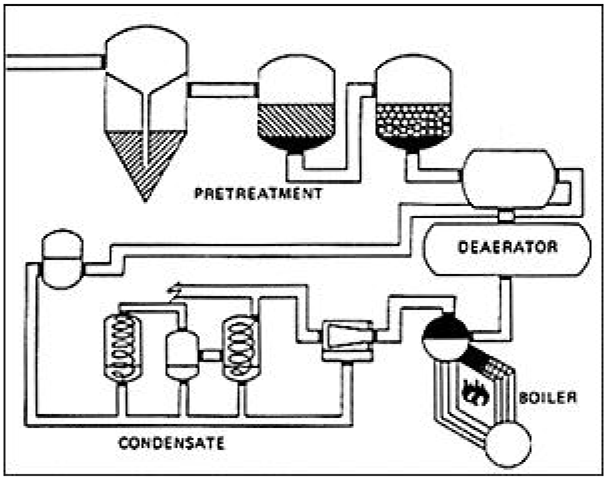

The purpose of a boiler is to produce steam for heating, for plant processes, and for driving turbines that produce electricity. While boiler systems vary in shape and size, they typically consist of the Boiler and its support systems: Pretreatment, Condensate, and Feedwater.

Strict care and control will keep boiler systems operating at peak performance. Common problems to avoid are Impurities, Carryover, Corrosion, and Deposits. Find out more about Nalco total system approach to boiler treatment programs.

Internal Boiler Treatment

Billions of pounds of steam are generated each day worldwide using boiler treatment programs. Proper water treatment can provide a measurable return on your investment with savings in fuel, water, chemicals and repairs.

Proper boiler treatment

- reduces utility costs
- extends the life of boilers
- improves boiler efficiency
- cuts downtime
- lowers maintenance costs

Nalco addresses water conditions related to hardness, oxygen, silica, iron and more. In low pressure boilers internal treatment may be the only treatment necessary because much of the condensate is returned and the raw water is of good quality. Moderate and high pressure boilers require both external pretreatment and internal treatment. Deposit control is critical in preventing costly boiler tube failures or wasted fuel.

Benefits of Nalco programs such as TRANSPORT PLUS® include:

- boiler cleanliness for optimized heat transfer, lower fuel bills, and fewer tube failures
- lower corrosivity for increased boiler reliability and fewer unplanned shutdowns due to corrosion
- superior passivation to further protect feedwater and boiler surfaces from corrosion and unnecessary repair costs
- low solids contribution which allows higher cycles and results in less water, Btu's and chemical blown down the drain
- ease in feeding and control to help assure optimum results

To further optimize your system, learn more about Nalco´s treatment feed, monitoring and control:

When is internal treatment of boiler feedwater necessary?

Chemical treatment of water inside the boiler is essential whether or not the water has been pretreated. Internal treatment, therefore, compliments external treatment by taking care of any impurities entering the boiler with the feedwater (hardness, oxygen, silica, iron regardless of whether the quantity is large or small.

In some cases external treatment of the water supply is not necessary and the water can be treated by internal methods alone. Internal treatment can constitute the sole treatment when boilers operate at low pressure, much of the condensate is returned and the raw water is of good quality. However, in moderate and high pressure boilers, external pretreatment of the make-up water is mandatory for good results. With today's higher heat transfer rates, even a small deposit can cause tube failures or wasted fuel.

What should a good internal water treatment program accomplish?

The purposes of an internal treatment program include:

- to react with incoming feedwater hardness and prevent it from precipitating on the boiler metal as scale
- to condition any suspended matter such as hardness sludge in the boiler and make it nonadherent to the boiler metal
- to control the causes of boiler water carryover
- to eliminate oxygen from the feedwater
- to provide enough alkalinity to prevent boiler corrosion

In addition, a complete treatment program should prevent corrosion and scaling of the feedwater system and protect against corrosion in the steam-condensate systems.

What chemicals are used in internal treatment?

Today's modern powerhouse uses a wide variety of internal treatment chemicals. Phosphates had been the main scale conditioning chemical until development of chelate and polymer type chemicals. Chelant programs offer superior cleanliness over phosphate programs, however, one weakness is the potential for corrosion if overfed. Polymer treatment, Nalco Transport Plus, offers cleanliness similar to chelates with less potential for boiler corrosion. All internal treatment, whether phosphate, chelant or polymer, condition the calcium and magnesium in the feedwater. Chelates and polymers form soluble complexes with the hardness, whereas phosphates precipitate the hardness.

Sludge conditioners (natural organic materials and synthetic polymers) aid in the conditioning of precipitated hardness. These materials must be effective and stable at boiler operating pressures. Certain synthetic organic materials are antifoam agents.

For feedwater oxygen scavenging, the chemicals used are sodium sulfite, Nalco SUR-GARD® or ELIMIN-OX®. Volatile neutralizing amines or filming inhibitors protect condensate systems.

How are internal treatment chemicals fed?

Common feed methods include the use of chemical solution tanks and proportioning pumps. In general, boiler treatment chemicals (polymers, phosphates, chelate, caustic) are added directly to the feedwater at a point after deaeration but before the entrance to the boiler drum. Certain phosphates (ortho-type) should be fed into the steam drum of the boiler. The chemicals should discharge in the feedwater section of the boiler system so that reactions occur in the water before it enters the steam generating areas.

Chemicals added to react with dissolved oxygen (sulfite, SUR-GARD®, ELIMIN-OX®) should be fed continuously into the deaerator neck or below the waterline in the deaerator storage section. Similarly, chemicals used to prevent scale and corrosion in the feedwater system (caustic, organics) should be fed continuously. Chemicals used to prevent condensate system corrosion may be fed directly to the steam, feedwater or boiler, depending on the chemical used. Continuous feeding is always preferred, but intermittent application may suffice in some cases.

How are chemical dosages controlled?

An operator can make manual adjustments based upon routine test results, however, automatic chemical control is preferable. Nalco automated control systems provide a reliable method for controlling the chemical treatment program.

Automation takes many forms:

- chemical addition may be proportioned to feed flow
- specific ion sensors, interfaced with a computer, can identify the proper treatment change and make adjustments
- a tracer can be used to maintain a product level at a set point or it can be interfaced with a computer to respond to a dynamic parameter

Proper proportioning and feeding of chemicals is needed to ensure the recommended amount of treatment is maintained continuously. Automated control systems, such as Nalco TRASAR® Technology, are becoming more prevalent. Conductivity-based systems for blowing down boiler water to reduce the level of suspended solids and dissolved solids are also used.

Pretreatment

The pretreatment system prepares the raw water (or make-up water) before it goes to the boiler. It could involve several pretreatment steps, all acting to reduce the dissolved and suspended solids from the water. Chemical treatment helps you avoid unwanted impurities.

- **Lime-soda softening** — Precipitation chemicals are added to react with dissolved minerals and form heavy suspended particles.
- **Filtration** — Removes such impurities as silt, clay and some organic materials.
- **Ion Exchange** — Removes dissolved solids by passing the water through natural or synthetic resins. The Nalco Resin Rinse program has been proven to control resin fouling and reduce operating costs. (Sodium zeolite softening, Dealkalization and Demineralization are ion exchange processes).
- **Reverse Osmosis(RO)** — RO utilizes a "cross-flow filtration" method that has three streams (feed, permeate and concentrate). This method uses a pressurized feed stream that flows parallel to the membrane surface. Nearly pure water passes through the membrane, which is the permeate, leaving behind the ions and solids in the concentrate. Since there is a continuous flow across the membrane surface, the rejected particles do not accumulate and plug the membrane, but instead are swept away by the concentrate stream.
- **PermaCare International** — Previously part of the Aquazur Group, PermaCare International is now a group in the New Nalco, focused on reverse osmosis (R/O) membrane treatment chemicals. With over 20 years practical experience in membrane technology throughout the world, PermaCare satisfies customer needs through an extensive range of products and technical services designed to improve the performance of membrane separation systems. The products include scale inhibitors, cleaners, and biocides marketed under the trade names PermaTreat™ and PermaClean™.

Condensate Treatment

Steam that has been used in various plant processes condenses and is returned to the boiler. Condensate is another component of feedwater, along with make-up water from the pretreatment area of the system. The danger of contamination by plant process materials is very great. Some contaminants include oil, chemicals, gases, cooling water.

If the condensate system is not properly protected, corrosion can result and lead to leaks and possible shutdown. As corrosion takes place, iron and copper compounds are washed back into the boiler systems and can plug up deareators and form deposits in the economizer and the boiler.

Through proper treatment, you can prevent a decrease in boiler efficiency, and the overheating and rupture of boiler.

Nalco condensate corrosion inhibitors provide exceptional corrosion protection:

- increasing equipment life
- enhancing system reliability
- minimizing repair and maintenance costs

What causes corrosion in steam condensate systems?

Carbon dioxide and oxygen cause most condensate system corrosion. Carbon dioxide, dissolved in condensed steam, forms corrosive carbonic acid. If oxygen is present with carbon dioxide, the corrosion rate is much higher and is likely to produce localized pitting. Ammonia, in combination with oxygen, attacks copper alloys.

How is steam condensate corrosion prevented?

The general approach involves removing oxygen from the feedwater mechanically and chemically and providing pretreatment of the make-up water to minimize potential carbon dioxide formation in the boiler. Chemical treatment reduces corrosion potential further. Volatile amines neutralize carbonic acid formed when carbon dioxide dissolves in condensate. Volatile filming inhibitors form a barrier between the metal and the corrosive condensate.

How do chemical oxygen scavengers help control condensate system corrosion?

Deaerators (and feedwater heaters) remove oxygen mechanically. The best-designed and operated deaerators can reduce oxygen to as low as 0.007 ppm. Since very small amounts of oxygen can cause corrosion, complete oxygen removal often requires chemical treatment. Sodium sulfite, Nalco ELIMIN-OX® and SUR-GARD® are chemicals commonly used for this purpose. Catalyzed sodium sulfite can reduce oxygen content of water (at room temperature) from the saturation point to zero in less than 30 seconds. Without a catalyst, it takes up to 10 minutes under the same conditions to reduce the oxygen content by only 30%. Oxygen should be removed before the water enters the boiler. Once in the boiler, oxygen leaves with the steam and causes corrosion problems in the condensate system.

What is the basis for choosing between neutralizing and filming inhibitors?

The proper choice depends on the boiler system, plant layout, operating conditions and feedwater composition. In general, volatile amines are best suited to systems with low make-up, low feedwater alkalinity and good oxygen control. Filming inhibitors usually give more economical protection in systems with high make-up, air in-leakage, high feedwater alkalinity or intermittent operation. In most cases, a combination of these treatments may be the best to combat condensate corrosion.

What characteristics should a good condensate corrosion inhibitor have?

A good volatile neutralizing amine should have a favorable distribution ratio in steam and condensate so that it protects the entire steam-condensate system. It should have no insoluble reaction products and should be stable at high temperatures and pressures. A good filming inhibitor should be easy to disperse in water. It should be stable under usage conditions and form a thin, protective film without causing deposits in either the boiler or steam-condensate system.

Boiler Feedwater

A boiler's efficiency is directly related to the quality of its feedwater. The feedwater system refers to deaerator, feedwater pumps, and the piping to the boiler.

Before water enters the boiler, oxygen must be removed or corrosion can occur throughout the boiler system, forming pits that eat away at the metal. Resulting leaks could lead to a blown boiler tube and ultimately could cause a power plant shutdown.

Nalco SUR-GARD® is an oxygen scavenger that works rapidly, effectively and safely to passivate deaerators, feedwater systems and boilers. It also reduces feedwater iron levels and insulating iron deposits on boiler tubes to help minimize fuel wastage.

Nalco ELIMIN-OX® has also been used worldwide to eliminate the problems caused by oxygen in boiler systems.

What is boiler feedwater?

Feedwater is water added to a boiler to replace evaporation and blowdown. In many cases, condensed steam returned to the boiler through the condensate system constitutes much of the feedwater. Make-up is any water needed to supplement the returned condensate. The make-up water is usually natural water, either in its raw state or treated by some process before use. Feedwater composition therefore depends on the quality of the make-up water and the amount of condensate returned.

How pure must feedwater be?

Feedwater purity is a matter both of quantity of impurities and nature of impurities. Some impurities such as hardness, iron and silica, for example, are of more concern than sodium salts. Feedwater purity requirements depend on boiler pressure, design and application. Feedwater purity requirements can vary widely. Low pressure, firetube boilers require less stringent feedwater control than modern high pressure boilers.

Which impurities form deposits?

Dissolved bicarbonates of calcium and magnesium break down under heat to give off carbon dioxide and form insoluble carbonates. These carbonates may precipitate directly on the boiler metal or form sludge in the boiler water that may deposit on boiler surfaces. Calcium sulfate, upon heating, becomes less soluble. Sulfate and silica generally precipitate directly on the boiler metal and ordinarily do not form sludge. For this reason they are much harder to condition and may cause more difficulties.

Silica is usually not present in very large quantities in water, but under certain conditions it can form an exceedingly hard scale. Suspended or dissolved iron coming in with the feedwater will also deposit on the boiler metal. Oil and other process contaminants can form deposits as well as promote deposition of other impurities. Sodium compounds do not deposit under normal circumstances. Sodium deposits can form under unusual circumstances: in a starved tube, a stable steam blanket or under existing porous deposits.

Removing Impuritites from Boiler Water

What is clarification?

Clarification is the removal of suspended matter and color from water supplies. The suspended matter may consist of large particles that settle out readily. In these cases, clarification equipment merely involves the use of settling basins or filters. Most often, suspended matter in water consists of particles so small that they do not settle out, but instead pass through filters. The removal of these finely divided or colloidal substances therefore requires the use of coagulants.

What is coagulation? What is flocculation?

Coagulation is charge neutralization of finely divided or colloidal impurities. Colloidal particles have large surface areas that keep them in suspension. In addition, the particles have negative electrical charges, which cause them to repel each other and resist adhering together. Coagulation requires neutralization of the negative charges, providing an agglomeration point for other suspended particles. Flocculation is the bridging together of the coagulated particles.

What is chemical precipitation?

In precipitation processes, the chemicals added react with dissolved minerals in the water to produce a relatively insoluble reaction product. Precipitation methods reduce dissolved hardness, alkalinity and, in some cases, silica. The most common example of chemical precipitation in water treatment is lime-soda softening.

Ion Exchange

What is ion exchange?

When minerals dissolve in water, they form electrically charged particles called ions. Calcium bicarbonate, for example, forms a calcium ion with positive charges (a cation) and a bicarbonate ion with negative charges (an anion).

Certain natural and synthetic materials have the ability to remove mineral ions from water in exchange for others. For example, calcium and magnesium ions can be exchanged for sodium ions by simply passing water through a cation exchange softener.

What are the various types of ion exchange resins?

There are two types of ion exchange resins: cation and anion. Cation exchange resins react only with positively charged ions such as Ca^{+2} and Mg^{+2}. Anion exchange resins react only with the negatively charged ions such as bicarbonate (HCO_3^-) and sulfate (SO_4^{-2}).

Although there are several types of cation exchange resins, they usually operate on either a sodium or hydrogen "cycle". A "sodium cycle" exchanger replaces cations with sodium; a "hydrogen cycle" exchanger replaces cations with hydrogen.

The two types of anion resins are: weak base and strong base. Weak base resins will not take out carbon dioxide or silica (actually carbonic acid and siliceous acid), but remove strong acid anions by a process that is more like adsorption than ion exchange. Strong base anion resins, on the other hand, can reduce silica and carbon dioxide as well as strong acid anions to very low values. Strong base anion resins are generally operated on a hydroxide cycle. *Dealkalization* reduces alkalinity through chloride anion exchange.

What is ion exchange regeneration?

Ion exchange resins have only a limited capacity for removing ions from water. Reversing the ion exchange process, regeneration, returns the resin to its original condition. Regeneration involves taking the unit off line and treating it with a concentrated solution of the regenerant. The ion exchange resin releases ions previously removed; these ions are rinsed out of the resin vessel. The ion exchange unit is then ready for further service.

In the case of cation exchangers operating on the sodium cycle, salt ($NaCl$) replenishes the sodium capacity or acid (H_2SO_4 or HCl) replenishes the hydrogen capacity. Anion exchangers are regenerated with caustic ($NaOH$) or ammonium hydroxide (NH_4OH) to replenish the hydroxide ions. Salt ($NaCl$) may be used to regenerate anion resins in the chloride form for dealkalization.

What is the purpose of deaeration?

Before the feedwater enters the boiler, oxygen must be removed. Feedwater deaeration removes dissolved oxygen by heating the water with steam in a deaerating heater or deaerator. A steam vent transports the oxygen out of the deaerator.

There are two basic types of steam deaerators: spray and tray. In the spray deaerator, a jet of steam mixes intimately with the feedwater being sprayed into the unit. In the tray type, the incoming water falls over a series of trays, where it is broken into small droplets and mixed with the steam. Tray-type deaerators also increase the residence time in the deaerator section.

What is reverse osmosis?

To understand reverse osmosis (RO), one must first understand osmosis. Osmosis uses a semi-permeable membrane that allows ions to pass from a more concentrated solution to a less concentrated solution without allowing the reverse to occur.

Reverse osmosis overcomes the osmotic pressure with a higher artificial pressure to reverse the process and concentrate the dissolved solids on one side of the membrane. Normal operating pressures are 300 to 900 psi. Reverse osmosis will reduce the dissolved solids of the raw water, making the final effluent ready for further pretreatment. Although sometimes expensive, this process can be used on any type water.

Carryover

What is boiler water carryover?

Boiler water carryover is the contamination of steam with boiler water solids. There are several common causes of boiler water carryover:

• Bubbles form on the surface of the boiler water and leave with the steam. This foaming can be compared to the stable foam of soap suds.

• Spray or mist is thrown up into the steam space by the bursting of rapidly rising bubbles at the steam release surface. This phenomenon is like the effervescence of champagne. No stable foam forms, but droplets of liquid burst from the liquid surface.

• Priming is a sudden surge of boiler water caused by a rapid change in load. (Uncapping a bottle of charged water produces an effect like this.)

• Steam contamination may also occur from leakage of water through improperly designed or installed steam-separating equipment in a boiler drum.

What causes foaming?

Very high concentrations of soluble or insoluble solids in boiler water will cause foaming. Specific substances such as alkalis, oils, fats, greases and certain types of organic matter and suspended solids cause foaming.

Corrosion

What is corrosion?

Stated simply, general corrosion is the reversion of a metal to its ore form. Iron for example, reverts to iron oxide as a result of corrosion. The process of corrosion, however, is a complex electro-chemical reaction. Corrosion may produce general attack over a large metal surface or may result in pinpoint penetration of the metal. Basic corrosion in boilers results primarily from the reaction of oxygen with the metal. Stresses, pH conditions and chemical corrosion have an important influence and produce different forms of attack.

Where is corrosion usually experienced?

Corrosion may occur in the feedwater system as a result of low pH water and the presence of dissolved oxygen and carbon dioxide. On-line boiler corrosion occurs when boiler water alkalinity is too low or too high. When oxygen-bearing water contacts metal, often during idle periods, corrosion can occur. High temperatures and stresses in the boiler metal tend to accelerate the corrosive mechanisms. In the steam and condensate system, corrosion is generally the result of contamination with carbon dioxide and oxygen. Additional contaminants such as ammonia or sulfur-bearing gases may increase attack on copper alloys in the system.

What other materials can cause boiler corrosion?

Excessive chelate residuals (in excess of 20 ppm as $CaCO_3$) or improperly applied chelate programs may produce boiler system corrosion. Concentrating boiler solids at a high heat input area might also produce boiler corrosion. To minimize the chance of corrosion, follow the recommendations of your Nalco water treatment consultant.

What problems are caused by corrosion?

Corrosion causes difficulty from two respects. The first is deterioration of the metal itself and the second is deposition of the corrosion products in high heat release areas of the boiler. Uniform corrosion of boiler surfaces is seldom of real concern. All boilers experience a small amount of general corrosion. Corrosion takes many insidious forms, however, and deep pits resulting in only a minimal total iron loss may cause penetration and leakage in boiler tubes. Corrosion beneath certain types of boiler deposits can so weaken the metal that tube failure may occur. In steam condensate systems, replacement of lines and equipment due to corrosion can be costly.

How is boiler corrosion measured?

With the trend toward higher heat fluxes in today's modern boilers, corrosion has become an important factor in power plant operation. When iron corrodes, hydrogen gas, which can be measured in the steam, is released. Measuring the amount of hydrogen gas released can detect immediate fluctuations in load, boiler water conditions or fuel changes. This information when interpreted by an experienced, well-trained engineer can indicate if corrosive conditions exist in an operating boiler.

What measures are taken to prevent boiler system corrosion?

The most common methods for prevention of corrosion include:

- Removing dissolved oxygen from the feedwater
- Maintaining alkaline conditions in the boiler water
- Keeping internal surfaces clean
- Protecting boilers during out-of-service intervals
- Counteracting corrosive gases in steam and condensate systems with chemical treatment

The selection and control of chemicals for preventing corrosion require a thorough understanding of the causes and corrective measures. Your Nalco representative provides this expertise.

Deposit Control

When is internal treatment of boiler feedwater necessary?

Chemical treatment of water inside the boiler is essential whether or not the water has been pretreated. Internal treatment, therefore, compliments external treatment by taking care of any impurities entering the boiler with the feedwater (hardness, oxygen, silica, iron) regardless of whether the quantity is large or small.

In some cases external treatment of the water supply is not necessary and the water can be treated by internal methods alone. Internal treatment can constitute the sole treatment when boilers operate at low pressure, much of the condensate is returned and the raw water is of good quality. However, in moderate and high pressure boilers, external pretreatment of the make-up water is mandatory for good results. With today's higher heat transfer rates, even a small deposit can cause tube failures or wasted fuel.

What should a good internal water treatment program accomplish?

The purpose of an internal treatment program is fivefold:

- To react with incoming feedwater hardness and prevent it from precipitating on the boiler metal as scale
- To condition any suspended matter such as hardness sludge in the boiler and make it nonadherent to the boiler metal
- To control the causes of boiler water carryover
- To eliminate oxygen from the feedwater
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What chemicals are used in internal treatment?

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