NCDENR

Boiler Chemicals 101

FACT SHEET

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.

Except for a small number of specialty models, boilers generally fit into one of the two common categories: fire-tube boilers and water-tube boilers. Fire-tube boilers pass hot combustion gases through tubes submerged in water. Water-tube boilers, on the other hand, circulate water inside the tubes in a closed vessel filled with hot combustions gases. In either category the boiler feedwater and fuel often contain impurities, which impairs boiler operation and efficiency. Chemical additives can be used to correct the problems caused by these impurities. To improve feedwater quality, fuel oil condition, and steam purity, these chemicals can be injected directly into the feedwater, steam or fuel oil.

This fact sheet discusses the potential problems associated with the impurities in the feedwater and fuel and the chemical treatment programs available.

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.

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). Fuel wasted due to scale may be approximately 2-5 percent depending on the scale thickness.

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.

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Acid attack is another common causes 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 (CO_2) by the heat and pressure of the boilers. CO_2 is carried over in the steam. When the steam condenses, CO_2 dissolves in water to form carbonic acid (H_2CO_3) and reduces the pH of the condensate returning to the boilers. Acid attack may also impact condensate return piping throughout the facility.

Chemical Treatments

- Lime Softening and Soda Ash
  Quick or slaked lime (usually calcium hydroxide) 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. Please see the basic boiler system schematic illustrated on page 3.

- 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.

- Chelates
  Nitrilotriacetic acid (NTA) and ethylenediamine tetraacetic acid (EDTA) are the most commonly used chelates. Chelates combine with hardness in water to form soluble compounds. The compounds can then be eliminated by blowdown. The preferred feed location for chelates is downstream of the feedwater pump. A stainless steel injection quill is required. However, chelates treatment is not recommended for feedwater with high hardness concentration.

- Polymers
  Most polymers used in feedwater treatment are synthetic. They act like chelates but are not as effective. Some polymers are effective in controlling hardness deposits, while others are helpful in controlling iron deposits. Polymers are often combined with chelates for the most effective treatment.

- 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.

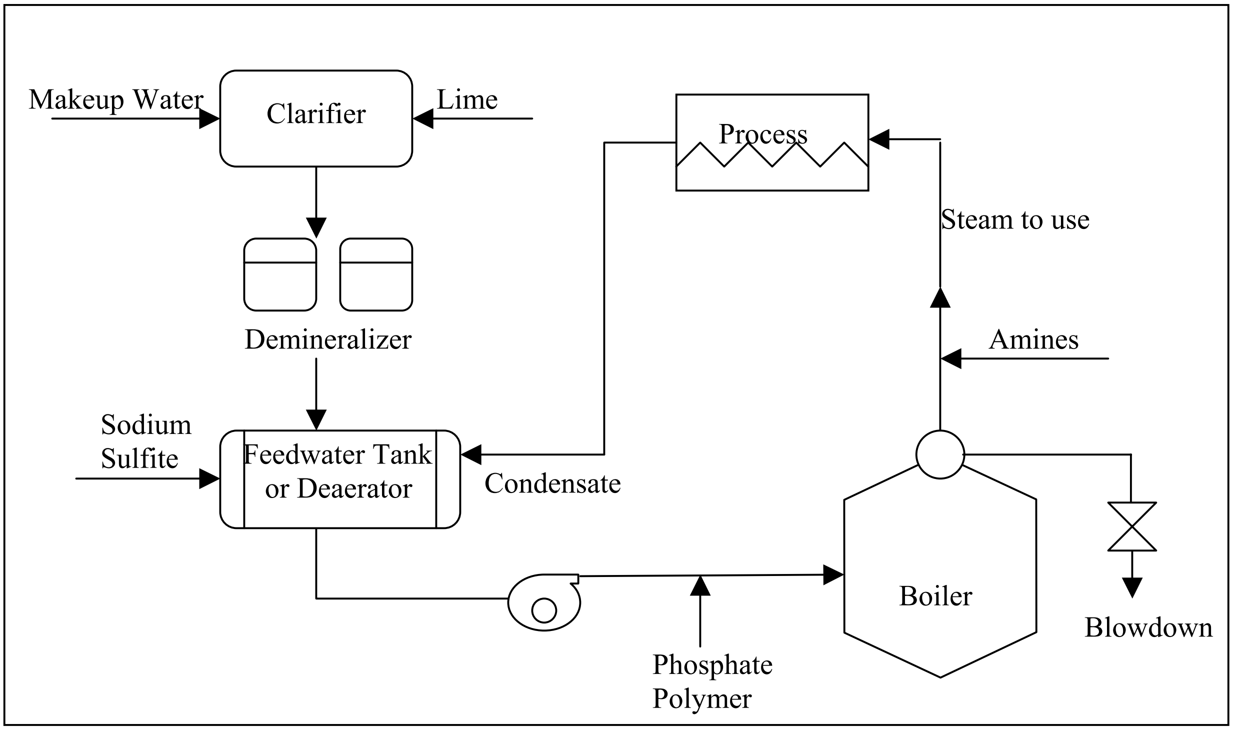
- Neutralizing Amines
  Neutralizing amines are high pH chemicals that can be fed directly to the feedwater or the steam header to neutralize the carbonic acid formed in the condensate (acid attack). The three most commonly used neutralizing amines are morpholine, diethyleminoethanal (DEAE) and cyclohexylamine.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

- 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 filming amines should be continuously fed into the steam header with an injection quill based on steam flow. 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 basic boiler system schematic shown below illustrates the points of chemical addition for boiler water treatment.

Basic Boiler System Schematic



Below is a summary of problems associated with the common impurities in water and solutions to each problem.

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

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 performance can create domino effects increasing operating and maintenance costs. To select and establish the proper water treatment program, the operator and engineer must:

- Understand the problems and different treatment methods.
- Evaluate the overall cost and benefits. Selecting a program solely on the basis of the lowest cost is false economy.
- Have a qualified water chemist to monitor and ensure consistent water quality.
- Review blowdown practices to identify energy saving opportunities. Minimizing blowdown rate can significantly reduce energy losses. However, insufficient blowdown may lead to carryover of boiler water into the steam and formation of deposits.

Chemical Treatment for Fireside Boiler Tubes

A complete boiler efficiency program must concentrate not only on water quality but also on efficient and complete combustion of fuels. Fuels commonly used to create heat in boilers are nuclear fusion, electricity, the wastes of certain processes, natural gas, coal, wood and fuel oils. This section only discusses the problems associated with fuel oils. Commonly used fuel oil includes Nos. 2, 4, 5 and No. 6 oil. Fuel oils are complex combinations of chemical compounds–mainly saturated and unsaturated hydrocarbons. Both physical and chemical properties of fuels, such as flash point, viscosity and sulfur content, are important factors in determining the quality of fuels and the impact on boiler operation.

Boiler Fireside Fouling

Sludge is formed from reactions between heavier hydrocarbons, water and acid. Over time the sludge aggregates, hardens and eventually sticks firmly to solid walls. Sludge is often found in less turbulent sections of boilers. New sludge formed is the greatest concern because it can easily break loose from the tank and be drawn into the suction line of the boiler system.

Corrosion is generally related to the sulfur content in the fuel. Sulfur is the most undesirable impurity in fuel oil. Not only does it produce harmful emissions, but also sulfur compounds can combine with water, forming dilute sulfuric acid. Corrosion problems can also occur in the colder portion of the boiler system such as the chimney, air heater and economizers, when sulfuric and sulfurous acid condenses due to local temperatures below the dew point.

Soot is a soft black substance that can build up on the boiler fireside tube surface. Similar to scale buildup on the waterside surface, soot inhibits heat transfer, hence reducing boiler efficiency. A layer of soot of only 1/8 inch in thickness can reduces boiler efficiency by approximately 8.5 percent. Soot is caused by improper and incomplete combustion. Common causes of incomplete combustion include mechanical malfunctions, improper air-fuel ratio, improper fuel preparation, improperly designed combustion chambers, variable viscosity of oil, carbon residues, etc.

Chemical Additives

Fuel oil additives are usually liquid substances, often with no chemical analysis provided by the manufacturer. The perfect chemical additive prevents sludge formation by breaking existing impurities into a preferable state. Some chemicals convert sludge already present to burnable fuel. The chemical should be able to neutralize acids and form a monomolecular film at the metal surface to prevent corrosion and rust formation. In addition, the chemical additive should stabilize viscosity and provide more uniform flow of fuel oil to the burner for best possible combustion. Some products on the market can even reduce air pollution by minimizing the discharge of unburned hydrocarbons.

Considerations

To choose a proper chemical additive for fuel oil, the operator and engineer must take the following important principles into consideration:

- Choose a reputable manufacturer of chemical treatments to help select the proper additives.
- The suspected problems with the fuel oil currently in use must be determined before selecting an additive.

- A valid physical-chemical explanation of how the additive works must be explained.
- Lower grade fuel oils (residual or No. 6 oil) cause more serious fireside deposits.
- Natural gas fuel is less likely to cause fireside fouling. However, natural gas boilers should have their tubes inspected at least annually.
- Periodically cleaning the boiler tube heat transfer surface can significantly reduce fuel costs.

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The N.C. Division of Pollution Prevention and Environmental Assistance provides free, non-regulatory technical assistance and education on methods to eliminate, reduce, or recycle wastes before they become pollutants or require disposal. Contact DPPEA at (919) 715-6500 or (800) 763-0136 for assistance with issues in this fact sheet or any of your waste reduction concerns.

DPPEA-FY03-38