



Boiler Water Treatment

Risk Solutions

Hartford Steam Boiler
One State Street
P.O. Box 5024
Hartford, CT 06102-5024
Tel: (800) 472-1866
www.hsb.com

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Introduction

Water quality is a key factor in maintaining efficient, reliable boiler operation as impurities present in water can increase fuel costs or cause equipment damage. The loss of efficiency or equipment damage is created by scale, sludge or corrosion, that are all caused by water impurities. In addition to damage to the boiler, impurities in the water can carry-over in the steam, creating equipment damage throughout the steam system.

The intent of this white paper is to provide basic information on the common issues created by improper water conditions and identify the major components of a water treatment program including: important terms, equipment and chemicals used. The primary focus of this document is water treatment for lower pressure steam systems (less than 300 PSIG) encountered in most commercial or smaller industrial locations.

HSB recommends that boiler owners and operators follow the boiler manufacturer guidelines for water quality. These guidelines are available in the owner's operation and maintenance manual or from the original boiler manufacturer. Trained personnel should administer the water treatment program including regular boiler water testing and boiler cleaning if necessary. The program activities should be monitored and recorded in the boiler log. Many reputable companies are available to assist in setting up and running a boiler water treatment program tailored to the water conditions of the locale as well as the boiler type and process.

Issues Caused by Poor Water Chemistry

Scale

Hard water refers to common minerals such as calcium and magnesium salts that are dissolved in water. As water boils, these dissolved minerals are left behind and create thin hard layers of scale, with an eggshell type appearance, on the heat transfer surfaces. This hard scale first forms in areas with the greatest amount of heat transfer or at water/steam interfaces.



Scale on the tubes acts as an insulator, reducing heat transfer to the water. As less heat is transferred to the water, the exit flue gas temperature increases. This heat is then lost up the stack and is an efficiency loss. Each 40°F rise in exit gas temperature results in approximately a 1% decrease in boiler efficiency and therefore increased fuel usage and costs. A 1/16" thick layer of scale can result in a 7% decrease in efficiency. This efficiency loss is often hard to identify due to the gradual increase in scale. As scale continues to grow, the tube metal temperature begins to increase. If left uncorrected, the level of scale will raise the tube metal temperature to the point that the tube will begin to bulge and eventually fail.

Scale can be avoided or minimized by using water softeners and additives as discussed below.

Sludge

Sludge is formed as part of the water treatment additives. Sludge is soft when first formed, but if not removed quickly can form hard deposits that are difficult to remove. In watertube boilers this can lead to water starvation in tubes causing overheating and tube failures. In firetube or firebox boilers, accumulated sludge can result in water circulation issues and high metal temperature that also lead to overheating issues.

Boiler blowdown is effective in removing sludge provided it is in the soft stage. Consult the owner's manual for the proper procedure for your boiler model.

Corrosion

In addition to dissolved minerals, water also contains dissolved gases including oxygen (O₂) and carbon dioxide (CO₂). These gases can be introduced into the system through air in-leakage of the condensate system or through the make-up water. Carbon dioxide is also released as part of the scale forming process.

Oxygen in boiler water aggressively attacks boiler components. Oxygen attack generally appears as pits that form under tubercles (rusty looking projections, similar in appearance to barnacles). These tubercles can hide deep pits that can create a hole through the tube. Most oxygen corrosion is usually found in cooler areas of the boiler waterside surfaces, but can occur throughout the boiler and in the boiler feed water tank.

Carbon dioxide creates an acidic condition that can result in a general thinning of material or stress corrosion cracking in areas of high stress. In condensate piping, this acid can erode the bottom of the pipes and will often be seen as two grooves on the sides of the pipe. Corrosion is often observed as orange stains located at leaks in either the boiler or the condensate system. The orange rusty water may be seen in the gage glass. These symptoms should be addressed by an analysis and proper water treatment controls.

Corrosion is addressed by maintaining the boiler and condensate pH at appropriate levels and the use of deaerators, oxygen scavengers or amines as described below.

Carryover

Impurities carried over in the steam can foul downstream heat exchangers affecting heat transfer or can cause malfunctions in equipment such as valves, steam traps or pumps. Boiler carryover is a function of the boiler pressure, water purity and the function of the steam separation devices. Proper water treatment will help minimize the amount of carryover.

Water Treatment

Water treatment is the process where impurities in the water are removed and the water chemistry is maintained to eliminate the issues noted above. A key to proper water treatment is to match the water chemistry to the boiler or steam system design and use. Read the instruction manual for the boiler and understand the level of water quality needed in the boiler and for the makeup water. The best run systems obtain the correct quality with the minimum level of treatment. This results in minimizing both water treatment and water make-up costs while also optimizing performance and minimizing equipment risk.

The most effective way to minimize the amount of water treatment needed is to limit the amount of make-up water used. Repairing leaks in the steam and condensate systems and returning condensate back to the boiler system will minimize the water treatment costs and improve system issues resulting from make-up water.

Treatment Systems – External to the Boiler

Water Softener

Most water used in commercial and small industrial boilers comes from a municipal supply or from wells and suspended material is not an issue. The most prevalent contamination is water hardness which, as noted above, is due to minerals dissolved in the water. The most common system for removing these minerals is a water softener. In a water softener, boiler makeup water flows through a bed of resin beads that have high sodium (salt) content. This bed is also called a cation exchange bed. The sodium in the exchange bed replaces the calcium and magnesium in the water. This leaves higher sodium content in the boiler water. Sodium stays in solution at high temperatures and does not create scale in the boiler.

A softener system must be regenerated on a regular basis or the water will not be softened. Increasing chloride content is a potential indication that the softener needs regeneration or that there is another problem with the softener. System regeneration should be noted on the boiler log.

Water hardness values vary by geographic location so the requirements for water treatment vary by location. A local water treatment company will know typical constituents of the local water or may test to determine the level of incoming water quality.

Reverse Osmosis (RO)

RO systems are used when high quality water is required. A RO system uses a series of semi-permeable membranes located in a series of long cylinders. The water is pressurized on one side of the membrane and water diffuses through the membrane, but not the impurities. The impurities are flushed out as a brine solution.

Deaerators

A deaerator is used to remove oxygen and other dissolved gases from both the boiler makeup water and the condensate return. In a deaerator, incoming feedwater is sprayed through nozzles and mixed with steam. The steam heats the water, driving off dissolved gases. These gases are vented from the top of the deaerator and the deaerated water goes into a feedwater tank.

Treatment Systems – Internal

Chemical additives and boiler blowdown are used to control the water chemistry inside the boiler. Trained water treatment personnel should choose chemical additives with care based on steam system design, level and type of impurities in the water and the end use of the steam. For example, steam used for food processing or steam used in hospitals for humidification have specific regulations for allowable additives.

Chemical Additives

Chemical additives address a variety of issues including residual impurities in the water, residual oxygen levels and the pH level.

Phosphate compounds are common additives for boiler water treatment. Phosphate compounds react with any remaining hard water compounds to create a soft sludge that is eliminated through blowdown. Trisodium phosphate is the most common compound for lower pressure boilers. Phosphates also scavenge (or remove) any remaining oxygen and create a pH buffer to minimize corrosion potential. Sodium sulfite is another common oxygen scavenger that is added to the feed water.

Chelants and polymer compounds also address residual impurities by keeping them in solution. Compounds that remain in solution can then be eliminated by blowdown. A common dispersant is lingo-sulfonate. Phosphates, chelants and polymers can be used in combination.

Water pH is also a factor in helping to control scale build up and avoiding corrosion. pH is an indication of the water as either acidic or alkaline (or basic). Neutral water has a pH of 7, pH values of 0-7 are acidic and pH values of 7-14 are alkaline. Water in the boiler should be maintained at a pH of 11. At this pH level, minerals are less soluble, precipitate out and are removed with the blowdown. Sodium Hydroxide (also called caustic), Potassium Hydroxide and Phosphates are typical chemical additives used to control pH levels.

Amines are additives that reduce the acidity of condensate water and are called corrosion inhibitors. Boiler operators should maintain the condensate system at a pH of 7.5 to 8.5 to prevent acid corrosion. Most brands of corrosion inhibitors contain one or more of the following common amines; morpholine, cyclohexylamine and diethylaminoethanol (DEAE).



Blowdown

Blowdown is used to eliminate sludge that has formed and to reduce the concentration of impurities in the boiler. The quantity and type of blowdown (continuous vs. intermittent) is dependent upon the individual situation; water quality, water treatment program, boiler pressure and make-up water quantities. Intermittent blowdown should be performed during periods of low steam demand. Too little blowdown results in sludge or impurities that build-up to unacceptable levels, while too much blowdown results in wasted chemicals and heat loss. If dissolved solids build up in the boiler drum or shell, foaming and carryover can occur.

All water that is lost through blowdown must be replaced by make-up water.

Summary

Water quality is one of the pillars of a well-maintained boiler. Improper water treatment for boiler systems may cause equipment breakdowns as well as increased, but often unseen, efficiency costs. Boiler manufacturer's guidelines for water quality should be followed and all water treatment programs should be administered by trained personnel. For smaller commercial or industrial steam systems, water treatment programs can be set-up and managed by an outside water treatment service company that is experienced in boiler and steam systems.