BOILER/FEEDWATER GUIDELINES

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1.0 GENERAL

The purpose of this document is to provide basic guidelines to the inservice boiler inspector for boiler/feedwater treatment and the recognition of normal/abnormal boiler/feedwater conditions for power boilers, steam heating boilers, and hot water heating boilers.

2.0 ENVIRONMENTAL EFFECTS ON WATER

2.1 Earth's Hydrological Cycle

2.1.1 Water begins to evaporate as the sun heats up a body of water. This evaporated water gathers in the atmosphere and forms clouds. When the cloud water vapor cools sufficiently to condense, it begins to rain.

2.1.2 The rain is without impurities as it begins to fall. Because it is pure or content neutral (pH7), it is "hungry rain," with a high affinity for oxygen and carbon dioxide in the atmosphere. The rain droplets absorb oxygen and carbon dioxide as they pass through the atmosphere.

2.1.2.1 Some sources of carbon dioxide in the atmosphere are the combustion of fossil fuels, vegetation fermentation, and respiration.

2.1.2.2 This carbon dioxide contributes to making the rain acidic (acid rain) and is a major source of carbon dioxide found in the boiler's condensate return and feedwater system.

2.1.3 As the rain enters the ground, the acidic condition helps the water dissolve limestone. The limestone and other dissolved and suspended solids are obsorbed in the water.

2.1.3.1 These underground minerals, found in feedwater, are a major source of boiler scale.

2.2 Steam Boiler's Hydrological Cycle

2.2.1 A steam boiler's hydrological cycle (steam generation) is similar to that of the earth's hydrological cycle. In a steam boiler system, there are three potentially destructive elements: oxygen, carbon dioxide, and solids.

2.2.2 As the boiler water is heated and changes to steam, free oxygen is released, carbon dioxide is released from the solids, and the solids drop out (precipitate).

2.2.3 As the steam is used in the end process, it cools and condenses
The condensate, like the rain droplets, is "hungry condensate" with a high affinity

for carbon dioxide and oxygen. As the condensate cools, it becomes easier for gases such as carbon dioxide and oxygen to dissolve in the water.

2.2.3.1 Carbon dioxide is absorbed by the cooling condensate causing it to become acidic, thus creating a condition similar to “acid rain” found in the earth’s hydrological cycle. The acidic condition erodes/corrodes iron pipes, creating a trench in the bottom of condensate piping which sometimes corrodes through the pipe wall.

2.2.4 Free oxygen is also absorbed by the cooling condensate. Pits or holes in iron and steel components are caused by excessive oxygen in the boiler/feedwater. The accumulations of corrision products covered by unique nodules are called “tubercles.”

2.2.5 Iron, eaten away by “acid rain” and oxygen corrosion, is transported to the boiler, where it becomes an insulating deposit. It restricts heat transfer, which can cause overheating damage to the tubes and inefficiency leading to a waste of fuel

2.2.5.1 If iron-laden condensate leaks out of the system in route to the boiler, it usually will form an orange stain on the floor or other equipment. When observed, this stain is an indication that water treatment control practices should be reviewed.

3.0 WATER TREATMENT OBJECTIVES

3.1 External and Internal Water Treatment

3.1.1 Proper treatment of makeup water and/or feedwater is necessary to prevent corrosion, scale, and other deposits in pre-boiler, boiler, steam, and condensate systems, and to provide the required steam purity. Absence of adequate external and internal treatment can lead to operational upsets or unscheduled outages. Inadequate treatment can also be ill-advised from the point of view of safety, economy, and reliability. The reduction or removal of objectionable constituents by pretreatment external to the boiler is always preferable, and more reliable than, management of these constituents within the boiler by internal chemical treatment.

3.2 Oxygen Corrosion

3.2.1 Oxygen in the presence of water cooler than 212°F can cause a serious destructive activity called oxygen corrosion. The amount of oxygen absorbed in water is proportional to temperature and pressure. See examples below:

70° F water at 0 psig contains approximately 8.6 ppm;
150° F water at 0 psig contains approximately 4.3 ppm; and
212° F water at 0 psig contains approximately 0.0 ppm.

3.2.2 Dissolved oxygen can be eliminated in a boiler system by utilizing a deaerator feed tank, heated feedwater, or treating the feedwater in the condensate tank. Introducing an oxygen scavenger into the feedwater system will also help eliminate any dissolved oxygen in the feedwater.

3.2.3 During an internal inspection, the in-service inspector should look closely for “rusty, crusty looking knobby projections” (tubercles) scattered throughout the boiler and boiler piping. These tubercles are the by-product of, and typically cover oxidation corrosion. The size of the tubercle does not necessarily indicate the depth of damage; there may be a large, deep hole beneath a small tubercle and a small, shallow pit beneath a larger one. If not removed, oxygen corrosion will continue until holes are formed through the vessel wall. Even if the oxygen is removed from the wet side, once formed it will continue to form a hole using a different mechanism called “concentration cell” corrosion. The only way to completely stop the corrosion at this site is to remove the tubercle and the concentration of iron oxide and corrision products under it.

3.2.4 Most often oxygen corrosion is found in wet stored boilers and feedwater tanks that have prolonged cooler temperatures. To reduce the chance of corrosion in boilers and feedwater tanks, the water should be thoroughly mixed with an adequate amount of oxygen scavenger and heated to boiling while being vented to drive off oxygen at the start of storage.

3.3 Acid Corrosion

3.3.1 Raw water, as received through the city mains or wells, contains impurities including carbon dioxide. As condensate cools, it becomes easier for any carbon dioxide gas present to dissolve in the water. Carbon dioxide combined with water can form carbonic acid with a range of pH from 6.9 to 4.4.

3.3.2 This acidic condition occurs in steam condensate piping systems. If the piping is carbon steel, it is likely that the pipe will be damaged. This damage can be general overall corrosion, localized pitting, or cracking in stressed metal.

3.3.3 High temperatures accelerate the reaction. If uncorrected, serious pitting can result with possible rupture of boiler condensate piping or boiler tubes.

3.3.4 Rusty water in the boiler gage glass is a sure sign of acid corrosion in the boiler feedwater/condesate system or in the boiler itself.

3.3.5 Make-up water is the major source of carbon dioxide. The first priority is to minimize the amount of make-up water.

3.3.5.1 Logging make-up water readings can aid in determining the amount of make-up water being used. Repairing leaks on the boiler and boiler feedwater/condensate system will reduce the amount of make-up water used.

3.3.6 The second priority in reducing carbon dioxide is utilizing external pretreatment before the water enters the boiler. Dealkalizing the make-up water will reduce solids that are one of the major sources of carbon dioxide.

3.3.6.1 External pretreatment methods include filtering, softening, and dealkalizing the water.

3.3.7 Utilization of chemical treatment is the third priority in reducing any remaining solids that may be a source of carbon dioxide.

3.3.7.1 The solids that remain after external pretreatment can be treated internally with a variety of treatment chemicals. The boiler water should be maintained at pH 11. This may require an addition of alkaline if the water is not soft. A chemical called a sludge conditioner can be added to treat the solids so that they drop out (precipitate). These treated solids then must be removed from the boiler by blowoff.

3.4 Scale Deposits

3.4.1 All raw water contains dissolved salts. Water that has a high level of desolved salts is known as hard water. Where the water is hard, these are mainly calcium silicates and magnesium compounds. Under boiler operating conditions, these salts come out of solution and form scale deposits on the hot boiler metal. This is due to the decomposition of bicarbonates and to the decreased solubility of calcium salts at higher temperatures. As the water is evaporated, the solids are left behind and the scale deposits build up.

3.4.2 Scale forms an insulating barrier on the boiler tubes and other surfaces resulting in a decrease in heat transfer and lower efficiency. Scale deposits can also cause overheating and failure of boiler metal.

3.4.3 Scale forms as either hard or soft scale.

3.4.3.1 Hard scale is formed in firetube steam boilers on tubes and the shell in contact with boiler water and at the steam and water interface. In watertube boilers, hard scale forms at the steam and water interface of the steam drum shell or flash chambers and on the inside of the boiler tubes in contact with boiler water. Hard scale has the appearance of a white or brown concrete and has a smooth texture.

3.4.3.2 Soft scale is usually found in hot water heating/supply boilers and systems. It has the appearance of thick black or brown sludge and forms in or around the boiler tubes, on the boiler shell, and throughout the heating system.

3.4.4 Scale can be removed by mechanical or chemical means in accordance with the boiler manufacturer's recommendations.

3.5 Solids

3.5.1 Solids cause many problems throughout the entire boiler system. External pretreatment methods include filtering, softening, and dealkalizing. Those solids which remain after external pretreatment can be treated within the boiler with a variety of chemicals.

3.5.2 At least two conditions should be controlled with treatment. First, the boiler water should be maintained at pH 11. This may require an addition of alkali if the water is not soft. Secondly, a chemical called a sludge conditioner can be added to treat the solids so that they drop out (precipitate). Finally, these treated solids must be removed from the boiler by blowoff.

3.5.3 Dissolved solids in the water are in solution and cannot be seen. Dissolved solids are measured with a conductivity meter in micro-Siemens per centimeter (μS/cm) measured as Total Dissolved Solids (TDS) in ppm. The boiler manufacturer's recommendation for the conductivity or TDS should be followed.

3.5.3.1 The following are examples of TDS in water:

Lake water has approximately 180 ppm of dissolved solids. 1,000,000 pounds of this water will contain approximately 180 pounds of solids. A 100 hp boiler vaporizing 3,450 pounds of this as make-up water would leave behind 0.62 pounds of solids.

Well water can have as high as 1,250 ppm of dissolved solids. 1,000,000 pounds of this water will have 1,250 pounds of solids. A 100 hp boiler vaporizing 3,450 pounds of this as make-up water could leave 4.3 pounds of solids behind.

3.5.4 Suspended solids are insoluble and are measured in Total Suspended Solids (TSS). Suspended solids refer to small solid particles which remain in suspension in the boiler water.

3.5.5 Blowdown and Blowoff

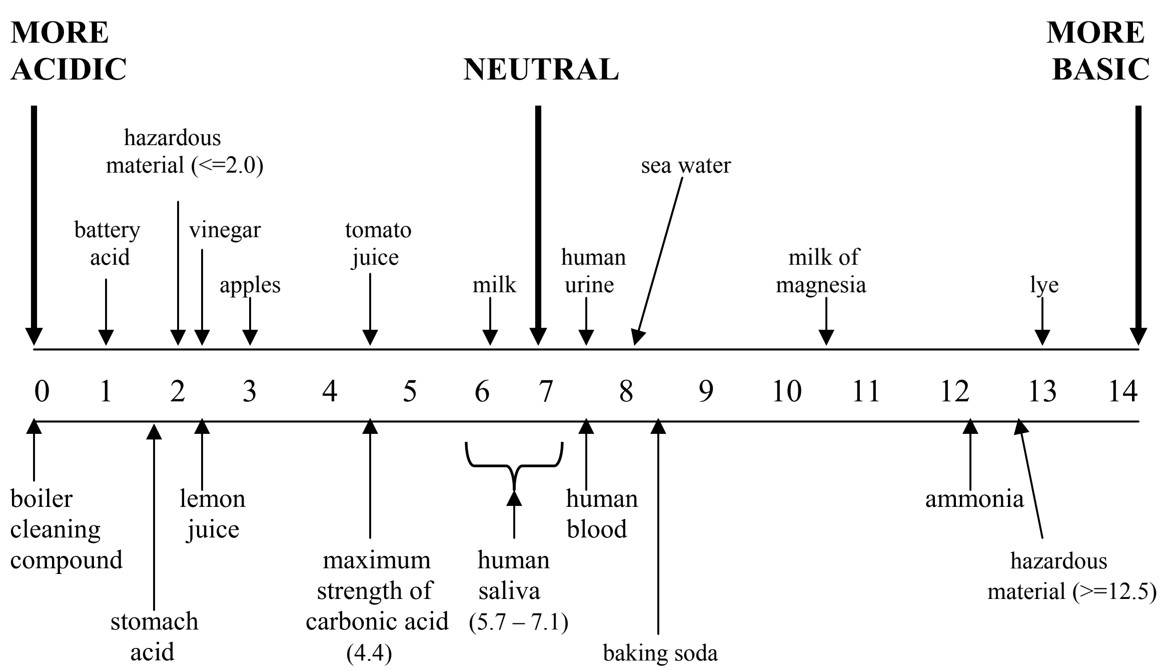
3.5.5.1 The purpose of blowdown and/or blowoff is to keep the amount of dissolved solids, suspended solids, and sludge in the boiler water under control. As water is turned to steam, the solids remain behind. Unless there is 100% condensate return, the solid content tends to build up. As a rule of thumb, about 1000 ppm can be considered a safe maximum. A hard water containing 200 ppm in the feedwater would tolerate five concentrations in the boiler (200 times 5 = 1000). On the other hand, a soft water with 25 ppm could be concentrated 40 times before reaching the critical point (40 times 25 = 1000).

3.5.5.1 Blowdown/blowoff should be minimized, because it involves removing boiler water with treatment chemicals.

4.0 Boiler/Feedwater pH

4.1 pH is an indication of the acidic or basic nature of water and other liquids. It can be indicated by taste, pH paper, or a temperature-adjusted pH meter.

4.2 The following numerical scale depicts pH values of a variety of materials for comparison:



4.3 Boiler water should be maintained at pH 11. Generally, the higher the pH (basic), the less soluble some solids are in the water. The lower the pH (acidic), the more soluble these solids are.

4.3.1 Hard scale is most often formed when dissolved solids are deposited directly on a heat transfer surface as water changes to steam. The preferred method of handling dissolved solids is to remove them from the water before they adhere to the tubes. A method to accomplish this is to raise the pH to 11, which makes the solids less soluble.

4.3.2 As more feedwater is introduced to the pH 11 boiler water, the feedwater dissolved solids are not soluble and tend to drop out of solution (precipitate) to form suspended solids.

4.4 Condensate should be maintained between pH 7.5 and 8.5. There is a natural tendency for condensate to be acidic (pH 6.9 – 4.4). Low pH can damage carbon steel piping systems. This low pH is caused by carbon dioxide (almost always present) reacting with the water to form carbonic acid (similar to acid rain) as the steam condenses.

4.4.1 On-line chemical treatment should be utilized to raise the pH to between 7.5 and 8.5. In this range, the carbonic acid is neutralized and damage is avoided.

5.0 Definitions

5.1 The following terms are common to boiler/feedwater and it's treatment:

Acid - any chemical compound containing hydrogen that dissociates to produce hydrogen ions when dissolved in water. Capable of neutralizing hydroxides or bases to produce salts.

Acidity - the state of being acidic; the degree of quantity of acid present.

Alkali - A solution of a substance in water which has a pH more than 7 and has an excess of hydroxyl ions in the solution.

Blowdown/Blowoff - the water removed under pressure from the boiler through the drain to eliminate sediment and reduce total solids. Surface blowdowns remove solids from the boiler’s waterline surface while bottom blowoffs remove solids from the bottom of the boiler.

Condensate - the water formed by the cooling and condensing of steam.

Corrode - to wear away gradually by chemical action.

Dealkalizing - to remove alkali from: reduce the alkalinity of (as by neutralization).

Erode - to eat into or away; destroy by slow consumption or disintegration.

Grains per gallon (gpg) - a measure used to denote the quantity of a substance present in water.

Micro-Siemens per centimeter (μS/cm)-a measure of the inverse of the amount of resistance an electric charge meets in traveling through the water.

Neutralize - the counteraction of acidity with an alkali or of alkalinity with an acid to form salts.

Parts per million (ppm) - the most commonly used method of expressing the quantity of a substance present in water; more convenient to use than percent due to the relatively small quantities involved.

pH - a scale used to measure the quantity of acidity or alkalinity of a solution. The scale runs from 1 (strong acid) to 14 (strong alkali) with 7 (distilled water) as the neutral point.

Phosphate - a generic term for any compound containing a phosphate group.

Precipitation - the formation and settling out of solid particles in a solution.

Soluble-capable of being dissolved in a liquid.

Suspended Solids-particles dispersed in and carried by water.