EWU COLLEGE

QUALITY WATER FOR

Steam Boilers

Technical Publication Number 0601920

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Steam Boilers

Contents

I. Introduction

One of the most common water softener applications is for softening the supply water to steam boilers. Most industrial and many commercial establishments require steam. Steam is used in textile mills to produce, form, and dye fabrics. The dry cleaner uses steam to iron linens. Canneries and meat packers cook or process foods with steam. Bakeries prepare bread with steam. The breweries use it to make beer. Boilers are used frequently for heating water in hotels, hospitals, laundries, and large buildings. It drives many of the turbines that produce electrical power. As a general rule, the larger the factory or industrial operation, the more apt we are to find one or more steam boilers in operation at that facility.

II. Boiler Operation

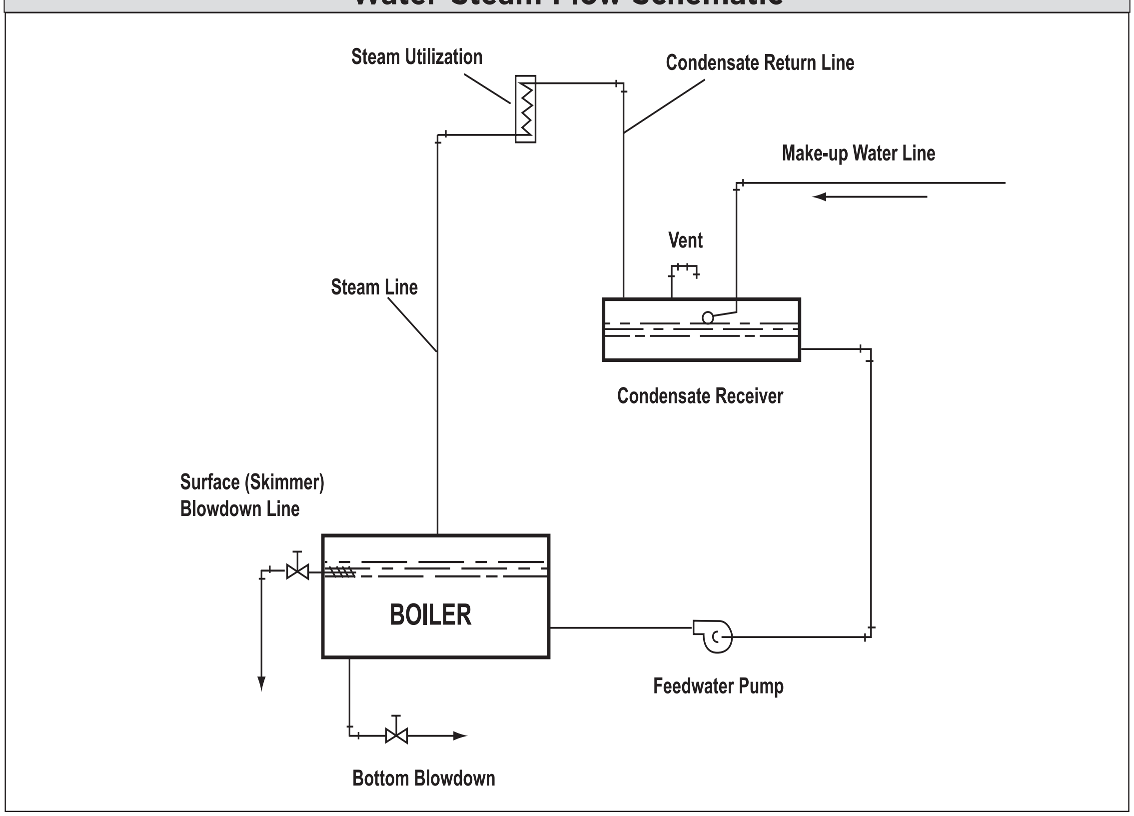
Steam Production

Most boilers have several things in common. Usually at the bottom is a firebox or combustion chamber (furnace) where the cheapest or most available fuel is fed through a burner to form a flame. The burner is controlled automatically to pass only enough fuel to maintain a desired steam pressure. The flame or heat is directed and distributed to the heating surfaces which are usually tubes, flues, or coils of fairly small diameter. In some designs the water flows through the tubes or coils and the heat is applied to the outside. These are called water-tube boilers. In other boilers, the tubes or flues are immersed in the water and the heat passes through the inside of the tubes. These are fire-tube boilers. If the water is subjected to the heated gases more than once, the boiler is a “two pass,” “three pass,” or “multiple pass” boiler.

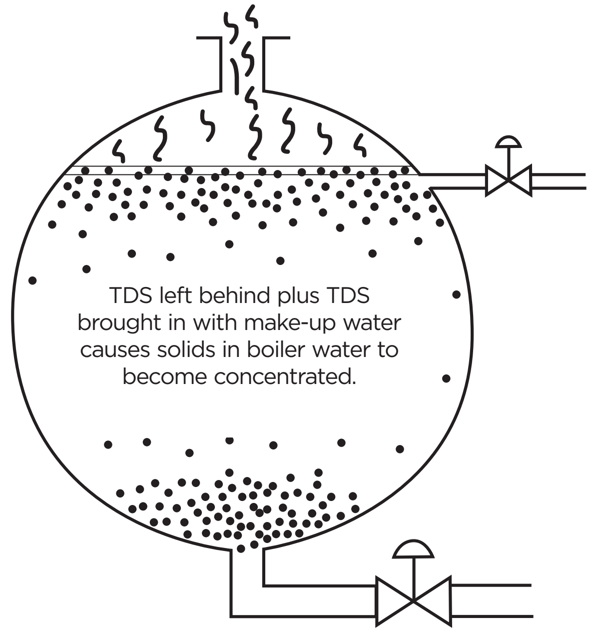
The heated water or steam rises to the water surface, vaporizes, and is collected in one or more chambers or “drums.” The larger the drum capacity, the greater is the ability of the boiler to produce large, sudden demands of steam. At the top of the firebox is a metal or brick chimney or “stack” which carries away the combustion by-products and varying amounts of unused fuel. At the bottom of the boiler, and usually at the opposite end from the firebox, is an outlet valve called a “blowdown.” It is through this valve that most of the dirt, mud, sludge and other undesirable materials are purged from the boiler.

Attached to the boiler are a multitude of safety controls to relieve the pressure if it gets too high, to shut off the burner if the water gets too low, or to automatically control the water level. A water column (sight glass) is provided so that the interior water level is visible to the operator.

Water-Steam Flow Schematic



Steam Boiler



Boiler Feed Water

The water for the boiler is usually stored in a "make-up" tank so that a sufficient volume of water is available for larger than usual demands. A constant level is maintained by a float valve similar in principle to the tank type toilet float control. A high pressure pump pulls the water from the make-up tank and pushes it into the boiler. Because most boilers operate at pressures higher than those of the water supply, the pump must raise the feed water pressure to somewhat above that of the boiler operating pressure.

Clean steam is pure water in the form of a gas. When it is cooled and condensed, it is pure water and it is referred to as "condensate." As it is condensed into water it contains considerable heat which can be utilized. It is nearly perfect boiler make-up or feed water since it has been stripped of dissolved minerals and foreign matter in the evaporation process.

Whenever possible, condensate is returned to the boiler and is collected in a tank called a "condensate receiver." When condensate is recovered, the receiver may also perform the functions of the make-up tank.

In some installations, condensate return may supply as much as 99% of the feed water and the higher the percentage of condensate the less water treatment is required. Other installations may use 100% make-up if for, various reasons, the condensate cannot be recovered, or if it is badly contaminated.

Boiler Pressures

The temperature and pressure at which a boiler operates have a definite relationship as shown in the following table:

Boiling Point of Water at Various Pressures

Temperature ºF	Temperature ºC	Pressure P.S.I.
212	100	0
300	149	52
400	204	232
500	260	666
600	316	1529
700	371	3080
705	374	3200

At normal atmospheric pressure, water boils at 212ºF (100ºC), at higher pressures the boiling point increases, reaching a maximum of 705ºF (374ºC) at a pressure of 3200 pounds per square inch. Above this temperature water cannot exist as a liquid.

Boiler Ratings

Boilers are rated by the amount of steam they can produce in a certain period of time at a certain temperature. The largest units produce 1,000,000 pounds per hour of steam. Boilers are also rated on a power basis. A boiler is rated at one horsepower for every 34.5 pounds of water it can evaporate per hour. Another definition is one horsepower for every 10 square feet of heating surface in a water-tube boiler or 12 square feet of heating surface in a fire-tube boiler.

II. Water Quality Control

Feed Water Considerations

Boilers require external pretreatment of the feed or make-up water regardless of the type of boiler or operating pressure. Internal chemical treatment is required, regardless of the extent of the external water treatment. The external treatment reduces the chemical feed dosages and total operating costs. This publication addresses primarily the use of hardness removal equipment. Control of Total Dissolved Solids and alkalinity levels are also important and we intend to review these areas as well.

Total Dissolved Solids Control

When water is evaporated and forms steam, the minerals or solids that were dissolved or suspended in the water remain behind in the boiler. To replace the water which is evaporated, we add make-up water with its normal load of minerals or solids. After a period of time the Total Dissolved Solids (TDS) within the boiler will reach a critical level. This level, on lower pressure boilers, is recommended not to exceed 3500 ppm. TDS above this range can cause foaming which will result in a carrying of the high concentration of TDS into the steam lines, valves, and steam traps. The increasing level of the TDS is known as "cycles of concentration." This term is used very often in the operation and control of a boiler system. A water supply that contains
175 ppm of TDS in the make-up water could be concentrated 20 times to 3500 ppm.

The maximum amount of TDS allowed in a low-pressure boiler is 3500 ppm. On higher pressure operated boilers the TDS limit is reduced in relationship to the pressure rating. (See the table located on the bottom of page 4.)

To control the maximum allowable level of TDS, the operator must open periodically the boiler's blowdown valve. Blowdown is the first step in boiler water control and it can be accomplished manually at given intervals. The frequency is dependent on the amount of solids in the make-up water and the amount of make-up water added. In larger or more critical boilers the blowdown may be automatic or continuous.

Alkalinity Control

In addition to controlling the cycles of concentration of TDS, the alkalinity must also meet the maximum criteria. The level of alkalinity within low-pressure boilers should not exceed 700 ppm. The presence of alkalinity above the 700 ppm level can result in a breakdown of the bicarbonate producing carbonate and liberate free carbon dioxide with the steam. The presence of carbon dioxide in the steam usually results in high corrosion of steam and return lines.

Dealkalization is a process whereby softened water is passed through a unit which contains anion resin. The anion resin removes anions such as sulfate, nitrate, carbonate, and bicarbonate. These anions are replaced by chloride. Salt (sodium chloride) is therefore used to regenerate the unit with the anion exchange resin.

The need to soften the water to a dealkalizer stems from the danger of hard water precipitating calcium carbonate, and magnesium hydroxide within the dealkalizer bed. In addition, the anion exchange bed is also subjected to fouling with suspended matter. Because the dealkalizer's resin is lighter than a conventional softener resin, the backwash rate is much slower and insufficient to remove the suspended matter. The use of a softener as pretreatment serves, therefore, as an additional safeguard in the use of a dealkalizer.

As in the control of TDS there are decreasing levels of allowable alkalinity concentration as the boiler pressure rating increases. This is offered in the table located on the bottom of page 4.

Hardness Control

The formation of scale deposits on boiler heating surfaces is the most serious problem encountered in steam generation.

The primary cause of scale formation is the fact that the solubilities of the scale-forming salts decrease with increase in temperature. Consequently, the higher the temperature (and pressure) of a boiler operation, the more insoluble the incrusting salts become.

The presence of scale within the boiler is equivalent to spreading a thin film of insulation across the path of heat travel from the furnace gases to the boiler water. The presence of the heat insulating material will retard heat transfer and cause a loss in boiler efficiency.

Even more important than the effect of scale in causing heat loss is the effect of scale in causing overheating of boiler metal and consequent tube failures. Costly repairs and boiler outage are the result of such a condition. The modern boilers with high rates of heat transfer, the presence of even extremely thin deposits of scale will cause serious elevation in the temperature of tube metal. The scale coating retards the flow of heat from the furnace into the boiler water. This heat resistance results in a rapid rise in metal temperature to the point at which failure results. The possible damage of such a failure is not only expensive, it is also dangerous, since the metal is under pressure.

The real fact on the data provided in this technical publication is that the presence of any scale should be prevented from forming in boilers by either internal (chemical) or external (water softener) methods. Most scale can be prevented from forming in boilers by the employment of external (water softener) treatment.

However, no system of external softening, regardless of the h igh degree of efficiency, is in itself adequate protection against boiler scale. The use of internal (chemical) treatment is also required as supplementary to an effective boiler scale control program. However, there will remain some small amount of hardness in the feedwater even with the use of a water softener. Therefore, chemical treatment is always required. Internal treatment alone is more expensive and increasingly so at higher hardness levels. The employment of a water softener in conjunction with a chemical treatment program is the most effective, reliable, safest, and economical means of boiler water quality control.

Quality Water Summary

Total Dissolved Solids (TDS)
The maximum allowable concentration of TDS within a low pressure boiler is 3500 ppm.

Alkalinity
The maximum allowable concentration of alkalinity within a low pressure boiler is 700 ppm.

Hardness
The maximum allowable hardness within any boiler should approach 3 – 5 ppm.

Obviously, as the table below indicates, the higher the pressure rating of a boiler, the more critical is the need to provide a higher degree of quality water.

IV. Softener Sizing

In the process of selecting a proper water softener for boiler feedwater treatment, several considerations must be reviewed: water analysis;
the boiler horsepower; and information pertaining to the recovery of the steam.

Water Hardness Analysis
Hardness is made up of calcium and magnesium. Hardness within natural waters will vary considerably, depending upon the source from which water is obtained. Sections of the country that have limestone formations generally have a high hardness content in the water. Since surface waters are diluted by rainfall, well water in the same area will normally have a much higher hardness than surface water since the flow is underground over rock layers.

The degree of hardness at any location should never be assumed. Every effort should be made to obtain a water analysis at the site of installation. This will assure accuracy in your selection process.

In order to determine the size of a water softener, the first procedure in the selection process is to determine the amount of hardness. If the water analysis reports express total hardness in parts per million (ppm), or mg/L hardness must be converted to grains per gallon (gpg).

Determining Make-up Volume
In order to determine the amount of water used to feed a boiler, calculations are necessary to convert the rating of the boiler to the maximum amount of make-up in gallons. Boiler ratings are provided in several forms. However, all can be and should be converted to a common factor of horsepower. For each horsepower, a feedwater volume of 4.25 gallons per hour is required. To convert other boiler ratings to horsepower, the following table should be referenced:

Boiler Rating	Factor Used To Convert to Horsepower per hour
Pounds of steam per hour	Divide by 34.5
BTU's	Divide by 33,475
Square foot area – water tube	Divide by 10
Square foot area – fire tube	Divide by 12

Upon determining the boiler horsepower rating, two additional factors are needed to be known in order to obtain the net amount of make-up water required in a 24 hour period.

Boiler Water Quality Recommendations at Increasing Temperatures

Boiler Steam Pressure (PSI)	Maximum TDS (ppm)	Maximum Alkalinity (ppm)	Maximum Hardness (ppm)
Low – 300	3500	700	20
301 – 450	3000	600	<5
451 – 600	2500	500	<5
601 – 750	2000	400	<5
751 – 900	1500	300	<5
901 – 1000	1250	250	<5
1001 – 1500	1000	200	<5
1501 – 2000	750	150	<5
2001 – 3000	150	100	<5

The first of these is to determine the amount of condensate return to the boiler. This information is generally known by the boiler operator or design engineer. The amount of condensate returned is subtracted from the maximum amount of boiler water make-up.

A very accurate method in determining the net amount of make-up water per hour, or the percent of condensate returned, can be simply calculated on existing operations by comparing a water analysis of the water from the condensate receiver tank and the raw make-up water. In comparing these two waters one can be very accurate in the amount of condensate returned to the system.

Example: A condensate receiver tank with a water containing 300 ppm of total dissolved solids (TDS) and a know factor of 600 ppm TDS in the raw water make-up supply would indicate a 50% condensate return. As described earlier in this publication, condensate is near perfect water (zero TDS) when it enters the condensate receiver. Therefore, when a raw water supply of 600 ppm TDS is diluted with 0 ppm TDS water at a one-to-one ratio, the result would be 300 ppm TDS. This would represent a dilution of 50% or a condensate return of 50%.

The final step in our gathering of data for the softener selection process is to obtain the number of hours in a day the boiler is operated. This is not only important in order to determine total make-up volume, it is also information required to determine the design of our softener system. A boiler operating 24 hours per day will require soft water at all times. Therefore, the design will require the use of two or more units. On systems operating 16 hours per day, the use of a single softener may meet the needs of the operation. Typically the time required to recharge a softener is approximately three hours.

Softener Selection

The following represents a typical boiler plant from which we can calculate the demand for a softener.

1. **Determine water hardness**
   Analysis received or taken is in parts per million (ppm). Convert to grains per gallon (gpg). 342 ÷ 17.1 = 20 gpg
2. **Determine boiler horsepower**
   Boiler rating is in pounds per hour of steam. Convert to horsepower per hour.
3. **Determine maximum gallons per hour make-up**
   Convert H.P. per hour to gallons per hour make-up. H.P. per hour = 4.25 = gallons per hour mak e-up.
4. **Determine amount of condensate returned to system and calculate net make-up requirement**
   Deduct the condensate returned from the total make-up water to determine net gallons make-up water per hour.
5. **Determine total daily water use requirements**
   Multiply the hours of operation by net make-up water per hour.
6. **Determine total grains of hardness to be removed daily**
   Daily water use = grains of hardness per gallon.
7. **Determine continuous flow rate**
   Divide hours net make-up water by 60 minutes to get gpm.

Softener Capacity Ratings

Softener should be sized to enable removal of daily amount of grains with half the maximum capacity of the system.

The continuous flow should be achieved at around 5 gpm per cubic foot of resin or less.

The stringent requirements to meet very low hardness levels usually dictate larger systems than non-boiler applications.

To meet the needs of a boiler system having a continuous demand of 24 hours per day, the selection of a softener system must be of a multi-operation. The use of two or more softeners provides 24 hour soft water.

Bibliography

1. The American Water Works Association, Inc., “Water Quality and Treatment,” Third Edition
2. N. A. Wynhausen, “Steam Boilers and Water Treatment,”
   Water Conditioning Magazine Publication, May, 1968
3. University of Wisconsin, “Survey of Pretreatment“ Processes for Boiler Feed Water,” May, 1973
4. Betz, “Betz Handbook of Industrial Water Conditioning,” Sixth Edition 1962, Fifth Printing 1972
5. Charles R. Peters, “Water Treatment for Industrial Boiler Systems,” Industrial Water Engineering Magazine November/December, 1980

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