

CHAPTER 4

WATER TREATMENT FOR BOILER PLANTS

SECTION I. INTRODUCTION

4-1. OBJECTIVES OF WATER TREATMENT

This chapter is an introduction to boiler water treatment. Boiler water requires treatment to protect both the boiler and the distribution system. Professional help will occasionally be required to solve specific problems. Further assistance may be obtained from the United States Army Engineering and Housing Support Center (USAEHSC), Fort Belvoir, Virginia 22060. The material in this chapter is designed to acquaint the operator with the reasons for treatment and the techniques available. There are four primary reasons for treatment of boiler water.

a. Minimize Corrosion of Boiler and Distribution System. Corrosion of the steam distribution system is the result of carbon dioxide and oxygen released from the boiler water. The carbon dioxide condenses to form carbonic acid which combines with the oxygen to attack the distribution system piping. Iron and copper particles are returned to the boiler as suspended solids which collect as boiler scale and sludge and promote corrosion in the boiler. Leaks in distribution system piping result in energy lost as steam or hot water. Additional raw water must also be treated to replace the water or steam lost, adding to the water treatment cost and quantity of impurities added to the system. Figure 4-1 illustrates oxygen pitting of a condensate pipe.

b. Minimize Boiler Scale Deposits. Boiler scale deposits act as insulation which can result in overheating of the tubes and subsequent tube failures. Deposits also reduce heat transfer through the tubes, causing higher boiler exit gas temperatures and lower boiler efficiency while promoting corrosion by allowing the concentration of impurities under the scale. Figure 4-2 illustrates a boiler tube which has failed due to scale.

c. Improve Efficiency of Operation. As noted above, control of boiler scale and system leakage due to corrosion helps to maintain a plant's operational efficiency. Effective boiler water treatment also reduces the energy lost in blowdown. Treatment chemical quantities are reduced and appreciable energy savings are realized when blowdown is reduced and condensate return quantities are increased.

d. Control Carryover. In steam boilers, water may, under some conditions, leave the boiler with the steam. This can result in deposits in superheater tubes as shown in figure 4-3, or in piping and turbines. Corrosion is encouraged under such deposits. Water carried over in steam can also

lead to water hammer which can be extremely damaging to piping and equipment.

4-2. IMPURITIES IN WATER

Absolutely pure water is not found in nature. The impurities in water include dissolved gases, chemical compounds, and suspended solids. Some of these impurities can be seen, while others can be detected by taste or odor and still others can be detected only by laboratory test. Potable water contains impurities that make it unsatisfactory for boiler use including hardness components, dissolved minerals, alkalinity, dissolved gases, suspended solids, and oils. Uncontrolled concentrations of these impurities in only parts per million ranges can cause major problems, while concentrations of oxygen in parts per billion cause corrosion problems.

a. Hardness. Hardness in water is the result of the presence of calcium and magnesium, which may be deposited as scale. Most of the calcium and magnesium entering the boiler or boiler water treatment system is combined with either a carbonate or a bicarbonate and is referred to as "carbonate hardness." Hardness is generally expressed in terms of equivalent calcium carbonate. Hardness ions may also be combined with sulfates, nitrates, or chlorides in which case they are referred to as "noncarbonate hardness." Calcium and magnesium are positively charged ions or "cations" when dissolved in water. Carbonate and sulfate are negatively charged ions, called "anions." Table 4-1 lists some of the cations and anions which are common to boiler water.

Table 4-1. Common Cations and Anions

Positive Ions (Cations)		Negative Ions (Anions)	
Al ⁺⁺⁺	Aluminum	Cl ⁻	Chloride
Ca ⁺⁺	Calcium	CO ₃ ⁻	Carbonate
Fe ⁺⁺	Ferrous Iron	HCO ₃ ⁻	Bicarbonate
Fe ⁺⁺⁺	Ferrous Iron	HCO ₃ ⁻	Bicarbonate
H ⁺	Hydrogen	PO ₄ ⁻	Phosphate
K ⁺	Potassium	SO ₄ ⁻	Sulfate
Mg ⁺⁺	Magnesium	SO ₃ ⁻	Sulfite
Na ⁺	Sodium	SiO ₃ ⁻	Silicate

(1) Calcium Carbonates.

Calcium bicarbonate is soluble and common in natural waters. It can decompose with the addition of heat or an increase in pH to form calcium carbonate and carbon dioxide. The reaction is:





FIGURE 4-1. CONDENSATE PIPE CORROSION



FIGURE 4-2. BOILER TUBE FAILURE CAUSED BY SCALE



FIGURE 4-3. SUPERHEATER TUBE SHOWING CARRYOVER DEPOSITS

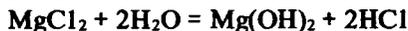
Calcium carbonate formed in the above reaction has a low solubility and forms a tenacious scale. The carbon dioxide is carried from the boiler with the steam. When the steam condenses, the carbon dioxide is dissolved in the condensate forming a weak carbonic acid solution which can corrode the metals in the condensate system and contaminate the condensate with dissolved metals.

(2) **Calcium Sulfates.** Various forms of calcium sulfate scale are found in boiler systems, the most important of which is gypsum, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$. The solubility of gypsum increases until the temperature reaches approximately 100°F and then gradually decreases. This scale has more than one hundred times the solubility of calcium carbonate at normal boiler temperatures.

(3) **Magnesium Bicarbonate.** Magnesium bicarbonate differs from calcium bicarbonate, in that it decomposes with the addition of heat to form magnesium hydroxide and carbon dioxide. The reaction is: $\text{Mg}(\text{HCO}_3)_2 = \text{Mg}(\text{OH})_2 + 2\text{CO}_2$

The magnesium hydroxide may form a sticky sludge or deposit as boiler scale. If silica is in the water, the magnesium hydroxide will react with the silica to precipitate magnesium silicate, which may be removed as sludge.

(4) **Magnesium Chloride.** Magnesium chloride, MgCl_2 , is very soluble. It reacts with water at the water-metal interface to produce magnesium hydroxide and hydrochloric acid. The reaction is:

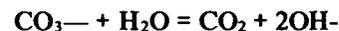


The hydrochloric acid is a gas which can leave the liquid water and corrode the boiler just above the water line.

b. Silica. Silica or silicon dioxide, SiO_2 , is found in abundance in nature. Common forms of silica include sand and quartz. Silica in boiler feedwater may precipitate and form a hard, glassy coating on the boiler surfaces. In boilers operating above 400 psig, silica vapor is carried over with the steam and deposited on turbine blades or piping. In treated boilers operating below 400 psig, silica is not troublesome because silica vapor is not formed. Phosphate treatment will prevent calcium silicate from forming scale by combining with the calcium, while sufficient alkalinity will keep the silica soluble. Excessive concentrations of silica can be limited by external treatment or continuous blowdown.

c. Iron and Other Suspended Solids. Iron corrosion products are probably the single largest cause of deposit problems in boiler systems. Condensate systems which have been attacked by carbon dioxide and oxygen are the major source of iron deposited in boilers. Iron from this source is a fine suspended solid. Other suspended solids which may enter the boiler and form porous deposits in low flow areas include copper, mud, sand, silt, clay, and dirt. Localized corrosion damage is encouraged at these deposits.

d. Dissolved Gases/Oxygen and Carbon Dioxide. Water that comes in contact with air will absorb oxygen and carbon dioxide. Raw water typically contains about nine parts per million of dissolved oxygen. While many impurities would be acceptable at this level, oxygen is not and treatment must be applied to reduce the oxygen levels a thousand times. Oxygen levels of less than seven parts per billion are necessary to avoid the pitting corrosion common to oxygen attack. Carbon dioxide may come either from air or from the reaction of carbonates with water. The reaction is:



This reaction creates two important results. First, carbon dioxide has been produced which may later present a corrosion problem in the condensate system. Carbon dioxide and oxygen are more corrosive in combination than they are separately. Secondly, hydroxide (OH^-) has been produced, and thus the alkalinity and causticity of the water have been increased.

e. Alkalinity/Causticity. The alkalinity of water tells the amount of acid that the water can neutralize. Alkalinity is the result of bicarbonates, carbonates, hydroxide, and other negative ions present in the water. Total alkalinity, or "M" alkalinity, is the amount of alkalinity that will react with acid as the pH of the sample is reduced to the methyl orange endpoint, approximately 4.3 pH. "P" alkalinity is the amount of alkalinity that will react with acid as the pH of the sample is reduced to the phenolphthalein endpoint, approximately 8.3 pH. Alkalinity is reported as parts per million of calcium carbonate, while causticity is the portion of the total alkalinity related to hydroxide ions (OH^-). Maintaining causticity within limits in boiler water is important to avoid corrosion from acids, promote good reactions between impurities, maintain impurities as dissolved solids, and ensure the desired relationship between calcium and phosphate. Alkalinity or causticity above desired limits can cause corrosive attack or carryover. Increasing causticity decreases the amount of hydrogen ions and acidity of water, as will be seen in the following discussion of pH.

f. pH. The pH is a measure of acidity or alkalinity of water. The test specifically measures the concentration of hydrogen ions in the water. A very small portion of pure water will ionize into equal parts of hydrogen (acidic) and hydroxide (alkaline) ions. The reaction is:



There will be .0000001 or (1×10^{-7}) grams per liter of each ion. Pure water thus said to have a pH of 7. Values of pH less than 7 are said to be acidic (contain more H^+ ions), while values greater than 7 are said to be alkaline (contain more OH^- ions). The pH scale is logarithmic. A pH of 5 is ten times as acidic as a pH of 6, while a pH of 4 is ten times more acidic than a pH of 5 and

a hundred times as acidic as a pH of 6. This is important to consider when adding a strong acid to a system, because 0.1 N sulfuric acid will have almost 100,000 times the acidity of neutral water. Adding one gallon of .1 N sulfuric acid to a system of 100,000 gallon capacity will double the acidity in the system. The pH of water is a very important factor in controlling corrosion. Very small changes in pH can significantly affect the solubility, reactions, and precipitation of impurities. Table 4-2 illustrates the relationships between pH, normality, and hydrogen ion concentration.

Table 4-2. Water pH

Nature	Hydrogen Ion Concentration		
	pH	Normality	H+ppm
Very Acidic (pH = 0 to 3)	0	10+(1)	1000
	1	10-1	100
	2	10-2	10
Acidic (pH = 4 to 6)	3	10-3	1
	4	10-4	.1
	5	10-5	.01
Neutral (pH = 7)	6	10-6	.001
	7	10-7	.0001
	8	10-8	.00001
Basic (pH = 8 to 10)	9	10-9	.000001
	10	10-10	.0000001
	11	10-11	.00000001
Very Basic (pH = 11 to 14)	12	10-12	.000000001
	13	10-13	.0000000001
	14	10-14	.00000000001

4-3. RESULTS AND REACTIONS OF BOILER WATER IMPURITIES

Scale, sludge, corrosion, and carryover are the results of boiler water impurities. The reactions of the impurities are discussed below.

a. Scale. Scale or sludge may be formed from either dissolved or suspended solids. In steam boilers impurities are concentrated in the boiler water as steam is produced. At a given temperature, pressure, and pH, a fixed amount of water can hold in solution only a fixed amount of any given substance. This is called the solubility of that substance. Water can hold great quantities of soluble substances like common salt, while less soluble substances like calcium carbonate, CaCO_3 , are not held in large quantity. If water holds too many Ca^{++} and CO_3 — ions, the excess calcium carbonate will precipitate out as either a scale on metal surfaces or as a sludge. When boiler water is treated with phosphate, the calcium hardness precipitates out as a calcium phosphate sludge because the calcium phosphate is less soluble than the calcium carbonate. This sludge can be removed with bottom blowdown. As scale is formed, it may collect suspended sludge or solids such as iron rust or silica. Typical scales may include calcium carbonate (CaCO_3), calcium sulfate

(CaSO_4), calcium silicate (CaSiO_3), or magnesium hydroxide (Mg(OH)_2). Scale may encourage corrosion, and may range from soft, porous, and easy to remove, to hard and extremely difficult to remove. Thickness and insulating effects of scales will also vary. Water treatment is used to minimize scale deposits by reducing hardness and other solids through external treatment and blowdown. Internal treatment is then used to promote favorable reactions and improve solubility.

b. Sludge. Sludge is an accumulation of suspended solids. These solids may have entered with the feedwater or precipitated from hardness ions in the water. Sludge is found in less turbulent sections of boilers and distribution systems. It may be sticky, and unless removed regularly, may settle on metal surfaces and form a scale. Excessive sludge may cause plugging in water wall headers, tubes, mud drums, blowdown lines, and gage glass connections. Calcium phosphate, iron rust, and silica are commonly found in sludge. Internal treatment with dispersants, like tannin, is used to keep sludge finely divided and fluid. Blowdown is used to remove the sludge.

c. Corrosion. Iron is found in its natural state as an oxidized compound, Fe_2O_3 , FeO , or Fe_3O_4 . Corrosion is an electrochemical reaction, and is nature's way of returning processed metals like steel, copper, and zinc to their natural states. The iron in steel boiler parts gives up two electrons as it goes into solution as Fe^{++} ions. The area where iron goes into solution is called the anode. Damaging corrosion will not occur unless the electrons released by the iron are removed from the steel by oxygen or hydrogen. The area where the electrons are removed is called the cathode. The fact that water can hold only certain amounts of iron ions in solution limits corrosion. Unfortunately, oxygen in water with Fe^{++} and OH^- ions can form ferric hydroxide (Fe(OH)_3) which precipitates out of the water. This reaction is:



This reaction occurs in both cold and hot water and allows more iron ions to enter the water. At higher temperatures, ferrous hydroxide reacts in water to form magnetic iron oxide or magnetite. Heating surfaces of boilers are usually black because of this insoluble black oxide which precipitates out of the water. The reaction is Ferric hydroxide can give up water to form insoluble ferric oxide, or hematite. Although many intermediate reactions occur, the final reaction is:



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To protect boilers and distribution piping from rusting, both external and internal water treatment is used to keep

oxygen levels in the parts per billion range or less. This stops corrosion by preventing electrons from being removed from the steel. Corrosion can also damage idle boilers if they are not protected by maintaining a high pH and deaerating the water.

(1) **Pitting.** Pitting is corrosion in a small area of a metal surface, often caused by oxygen in the water. These areas may be metallurgical defects, cuts, scratches, or crevices, either on the metal surface or under scale or sludge deposits. Oxygen reacts with ferrous ions to form insoluble ferric hydroxide. The ferric hydroxide forms a small hood (or "tubercule") over the area and induces an electrolytic current to flow through the metal. The current causes more iron to be converted to ferrous ions. The hood then grows as oxygen reacts with the ferrous ions, causing more ferric hydroxide to be precipitated. This action may continue until the metal is pitted completely through. Pits are usually started when the boiler is idle. Pitting is the most destructive type of corrosion that occurs in boilers or distribution systems.

(2) **Condensate Line Grooving.** Carbon dioxide leaving a steam boiler will condense with the steam, and carbonic acid will be formed as shown below:



This weak acid will lower the pH of the condensate and make hydrogen ions available to encourage corrosion. Ferrous ions will be removed from the steel and returned to the boiler plant as ferrous bicarbonate $\text{Fe}(\text{HCO}_3)_2$ or rust particles. Iron is typically removed from the bottom of the condensate pipe, causing a general thinning of the pipe wall, or grooving along the bottom of the pipe. Corrosion is most active where the steam condenses. Oxygen either from the boiler or from raw water entering the distribution system (e.g., through a leaking heat exchanger) will add to the corrosion problems. Raw water leakage can also cause scale and sludge problems in the boilers, and corrosion in the condensate return system.

(3) **Copper and Brass Corrosion.** Copper and brass corrosion is an electrochemical corrosion. In preventing this type of corrosion, it is important to protect distribution system heat exchangers from exposure to excessively high or low pH levels.

(4) **Caustic Corrosion/Caustic Embrittlement.** Excessive amounts of hydroxide in the boiler water can cause even higher concentrations of hydroxide to occur under scale deposits or at mechanical joints and can result in pitting corrosion or "caustic embrittlement." Caustic embrittlement is a specialized type of corrosion occurring at stressed points in the boiler. Once a common cause of boiler failure, improved fabrication techniques and better water treatment have made it rare.

d. Carryover. In steam boilers, poor boiler water quality can produce "carryover" of water droplets with the steam.

These water droplets will contain any impurities found in the boiler water. The contaminants in this carryover can cause fouling, blockage of equipment and corrosion. Carryover can occur in three ways: (1) foaming, (2) misting, and (3) priming. Foaming involves the production of a foam at the liquid-steam interface which is carried out with steam. High concentrations of dissolved and suspended solids, including alkalis, oils, fats, greases and organic matter, can cause foaming. Misting is characterized by fast-rising steam bubbles which burst and entrain water into the steam line. Priming involves a sudden surge of boiler water level, causing some of the water to be carried over into the steam. Mechanical causes of priming include carrying the water level too high, uneven fire distribution, and load characteristics or boiler design. Priming is also aggravated by impurities. Elimination of mechanical causes may require redesign of the boiler or steam drum internals, installation of steam purifiers, lowering of the boiler water level, better firing methods, or better boiler load regulation.

4-4. CONTROLLING IMPURITIES

Treatment of boiler water falls into three areas: external treatment, internal treatment, and blowdown. External treatment involves the pretreatment of makeup water to remove hardness, alkalinity, dissolved gases, and other impurities before the water enters the boiler. Internal treatment involves the introduction of chemicals directly into either the boiler feedwater just before it enters the boiler, or into the boiler drum itself. Impurities which enter a steam boiler from any source are concentrated as steam is produced. Blowdown involves the intermittent or continuous removal of this concentrated boiler water and sludge. A combination of external treatment, internal treatment, and blowdown must be used to effectively control impurities and resulting scale, sludge, corrosion, and carryover.

a. External Treatment. External treatment equipment and chemicals are available to remove impurities from the water before it enters the boiler. External treatment is discussed in Section II of this chapter. Removing impurities before they enter a boiler is the most effective way to protect the boiler and reduce water problems. Effective external treatment also helps to reduce internal treatment costs and improves boiler operating efficiency by reducing blowdown requirements.

b. Internal Treatment. The purpose of internal treatment is to prevent any problems in the boiler or distribution system caused by the impurities remaining after external treatment. Many methods of internal treatment are in use. The Army uses carefully controlled boiler water alkalinity, phosphate treatment to remove hardness, and an organic dispersant to condition suspended solids. The chemicals

used for internal boiler water treatment are inexpensive and readily available. Those most commonly used in Army boilers are caustic soda, a sodium phosphosphate, and quebracho tannin. Sodium sulfite is used to remove dissolved oxygen, while in steam plants, neutralizing amines are used to control condensate line corrosion. The amount of internal treatment is based upon maintaining the chemical within specified control limits. Continuous feeding of chemicals is recommended for best and most consistent control.

c. **Blowdown.** As steam leaves a boiler, the dissolved solids are concentrated in the remaining water. If this concentration were allowed to continue without control, the dissolved solids in the water would eventually precipitate out as scale or sludge and carryover could result. To prevent these problems, sludge is removed by intermittent bottom blowdown and dissolved solids are removed by continuous or intermittent blowdown from the boiler water line.

(1) **Rate of Blowdown.** The amount of feedwater to a boiler during a given period divided by the amount of blowdown during the same period gives the number of times the feedwater has been concentrated in a steam boiler called "cycles of concentration" or simply "concentration." Blowdown calculations are presented in appendix D. The rate of blowdown is controlled such that the concentration is as high as practical. The concentration that can be safely carried depends upon the particular installation. To determine the optimum concentration for a given plant, the concentration is gradually built up with the boiler operating on a typical load profile. Samples of condensed steam and boiler water are taken for analysis at the same time. The concentration of dissolved solids in the boiler water at the time that carryover first appears in the steam establishes the upper limit of concentration. Normally, however, it is not necessary to perform these tests. For average conditions, blowdown rate should be sufficient to maintain dissolved solids between 3,000 and 3,500 ppm. In addition, the rate of blowdown must be sufficient to prevent sludge accumulation, or problems from excess causticity or silica. Five percent blowdown (or 20 concentrations) are typical of a plant with good external treatment. In cases where this is not possible, consult the operating agency commander. The amount of blowdown must be adjusted in accordance with the load. As the boiler load increases or decreases, blowdown should be increased or decreased proportionately. If for any reason the percentage of condensate being returned to the boiler drops so that more makeup water is needed for the same load, a higher rate of blowdown may be required to maintain proper limits.

(2) **Continuous and Intermittent Blowdown.** Blowdown can be performed either continuously or intermittently.

Continuous blowdown is generally preferred because it allows closer control of boiler water solids and energy savings through reduced blowdown quantities. Blowdown can be controlled either manually or automatically based on boiler load or by using a conductivity monitor to actuate a throttling valve. Automatic blowdown control saves fuel and treatment chemicals by reducing boiler makeup requirements. Automatic blowdown controls can usually be justified for boilers with capacities of 10,000 pounds of steam per hour or more. Intermittent blowdown is less desirable and less economical because the solids concentration is allowed to fluctuate about the optimum level. However, the reduced equipment requirements may justify intermittent blowdown on small boilers having relatively low load requirements.

(3) **Location of Blowdown.** The location of blowdown is also a factor to consider in determining optimum blowdown rates. Bottom blowdown is necessary to remove settled sludge. Frequent bottom blows of short duration are more effective in sludge removal than occasional blows of longer duration. Long blows from bottom connections should also be avoided due to the danger of starving and overheating generating tubes. Blowdown for control of dissolved solids or other impurities is normally taken near the water level. Water is removed through a nozzle located about six inches below normal operating water level in an area away from the feedwater inlet.

(4) **Economics of Blowdown.** If the rate of blowdown is excessively high, heat (fuel), treatment chemicals, and water are all wasted. The most significant of these losses comes from the heat that is lost with the blowdown. Up to two percent of the total boiler heat input may be lost to blowdown. Heat exchangers which return part of this heat to the makeup water are recommended for all boilers operating with continuous blowdown. The high costs associated with wasted fuel can also justify upgrading of external treatment equipment to reduce blowdown requirements.

d. **Factors Affecting Boiler Water Treatment.** Many mechanical activities including operation of deaerators, water softeners, and blowdown systems affect boiler water treatment. Efficient operation of deaerators and venting of corrosive gases will help to control corrosion in boilers and condensate return systems, and reduce chemical treatment requirements. Efficient operation of water softeners will assure an almost hardness-free feedwater, further reducing the internal treatment requirements. Proper control of blowdown will also result in savings of treatment chemicals as discussed above. In addition, mechanical maintenance affects the boiler water treatment program. For example, maintaining a tight distribution system with little steam or condensate leakage results in a minimum of makeup requirements and consequently less chemical treatment.

The aims of boiler water treatment are achieved, therefore, by controlling the mechanics of treatment, maintenance, and chemicals.

e. **Technical Assistance.** Technical assistance is available from operating agency commanders for training of personnel in control of chemical treatment, testing procedures, related problems such as return-line corrosion, deaerator operation, and any other problems pertaining to water treatment.

4-5. TREATMENT REQUIREMENTS

Proper boiler water treatment is necessary to prevent scale, sludge, and corrosion within the boiler and distribution system. The type and extent of treatment required is determined by the nature of the raw water, the type of boiler, and the end use of the steam or hot water produced. Boilers are classified as follows:

Low Temperature Water	LTW (up to 250° F, less than 160 psi)
Medium Temperature Water	MTW (251° F to 350° F)
High Temperature Water	HTW (351° F to 450° F)
Low Pressure Steam	LPS (up to 15 psig)
High Pressure Steam	HPS (above 15 psig)

a. **Treatment Requirements for Steam Boilers.** Central boiler plants should be equipped with external treatment systems to reduce the sludge and scale potential of the boiler water, and with deaerators capable of delivering feedwater with low oxygen content at all operating loads. Where external treatment is not available, special precautions must be taken to blow down the boiler sufficiently to keep suspended solids at a low level, prevent sludge from forming on boiler surfaces and keep silica concentrations low enough to prevent deposits. Water treatment for high pressure steam boilers consists of caustic soda, sodium sulfite, sodium phosphate, and tannin, and must be maintained within control limits at all times. The deaerator should be operated to give dissolved oxygen values in the feedwater below 0.005 cc O₂ per liter (seven parts per billion) and a boiler water sodium sulfite residual should be maintained. Low pressure steam boilers may require water treatment based on size, makeup rate, age, type of boiler, local makeup water characteristics, and scale or corrosion problems. Where caustic soda, sodium sulfite, phosphates, and tannin are added to low pressure steam boilers, treatment is generally controlled to the same limits as in high pressure boilers. The desired boiler water limits for steam boilers producing saturated steam for heating or humidification only at less than 300 psig are given below. Comments on these limits and special cases are presented in the following paragraphs.

Causticity	20-200 ppm
Total Alkalinity	900-1200 ppm (CaCO ₃), see paragraph (10)
Phosphate	30-60 ppm
Tannin	Medium
Dissolved Solids	3,000-3,500 ppm, see paragraph (1,2)
Suspended Solids	100 ppm max, see paragraph (3)
Sodium Sulfite	20-40 ppm
Silica	Less than 150 ppm, see paragraph (10)
Dissolved Oxygen	Less than 7 ppb
Iron	10 ppm

(1) Maximum values may not be achievable in practice. The need to maintain causticity or suspended solids limits may override the total alkalinity and dissolved solids criteria.

(2) Current ABMA guidelines for total dissolved solids allow concentrations up to 5,000 ppm for boilers producing saturated steam at less than 250 psig for heating only. For boilers producing superheated steam, follow the manufacturer's recommendations for dissolved solids limits.

(3) For boilers designed to operate at moderate or low heat transfer rates, a suspended solids limit of 30 ppm is acceptable if the steam is used only for heating, and if excessive sludge does not develop. This generally includes boilers generating steam up to approximately 50 psig, especially those constructed prior to the mid- 1970's. For boilers producing higher pressure steam, or steam to be used to drive a turbine or other process, much lower limits, between 10 and 25 ppm are recommended. Follow the manufacturer's recommendations. Suspended solids are increased in the boiler by the use of phosphate chemistry (paragraph 4-7b). Phosphate ions which are introduced internally combine with residual calcium ions, under conditions of high pH, to form tricalcium phosphate. Since tricalcium phosphate is insoluble, it is retained in the boiler water as a sludge or suspended solid which must be removed by blowdown. The 30 to 60 ppm phosphate residual noted on the previous page is the soluble phosphate present over and above that required to precipitate out the calcium. This is sometimes called "excess phosphate." Since each ppm of calcium essentially reacts to form one ppm of suspended solid, it is important to size and operate softening equipment so as to minimize residual calcium hardness and therefore internal phosphate requirements.

(4) Low-pressure cast-iron steam boilers are not treated. If scale formation is observed, use inhibited sulfamic acid, as required, to remove the deposits.

(5) For steam boilers used in conjunction with cascade type hot water distribution systems, the limits are:

pH	9.3-9.9 (All steel systems may use a higher pH)
Causticity	20-30 ppm
Sodium Sulfite	30-60 ppm

The recirculating hot water distribution system limits are:

ph	9.3-9.9
Hardness	Less than 2 ppm

(6) When water-tube boilers of 35,000 pounds of steam per hour or greater capacity are operated at high loads, tannin may not be stable in the boiler water, and its use may lead to furnace tube deposits. In this case, it is preferable to operate without tannin. A lignin type dispersant may be used instead.

(7) Anti-foaming agents may be necessary in some cases.

(8) Low capacity steam boilers rated at capacities less than approximately 60 horsepower or 1,500 pounds of steam per hour need only be treated with caustic soda. A pH of 10 to 12 should be maintained. Boilers rated at 10 horsepower or less need not be treated unless warranted by local conditions.

(9) In boilers operating at less than 300 psig, silicate scale forms mostly as calcium silicate. Softening of the water to remove the calcium ions is generally sufficient to control this type of scaling.

(10) The 150 ppm limit for silica is a suggested guideline. Higher levels may be maintained provided that causticity is maintained at high enough levels to ensure silica solubility. The maximum silica level that is acceptable for an individual installation must be determined in the boiler plant, and should not exceed a level at which a buildup of sludge or scale occurs.

b. Treatment Requirements for Steam/Condensate Systems. For steam systems where amine treatment is economically justified, minimum condensate limits should be maintained between pH of 7.5 and 8.0. Higher values of pH may be required at some points in the system in order to maintain this limit.

c. Treatment Requirements for HTW and MTW Boilers. Treatment requirements of hot water systems differ greatly from those of steam systems. These systems are closed so that the only makeup water needed is to replace the water lost at pump glands and valve stems. Since makeup requirements are small, the accumulation of impurities is so small that blowdown is rarely needed. Makeup requirements even in the largest systems should not exceed 200-1,000 gallons per day. All makeup water introduced into a hot water system must be treated to remove the hardness. The water softening system should normally consist of dual zeolite tanks, brine solution tank, manually operated multi-port control valve, bell alarm water meter, and water distribution manifold. A deaerator is not required. Sodium sulfite is used to remove dissolved

oxygen. The desired boiler water limits for hot water systems are:

pH	9.3-9.9 (All-steel systems may have pH above 9.9)
Sodium Sulfite	20-40 ppm
Hardness	Less than 2.0 ppm

d. Treatment Requirements for LTW Boilers. LTW boilers may be treated as noted in paragraph c for HTW and MTW systems. Alternatively, all-steel LTW systems may be treated with borax-nitrite or, if copper piping is present, borax-nitrite with a copper inhibitor. The desired boiler and distribution water limit for this alternate is 1,500-2,500 ppm of borax-nitrite.