

Boiler Water Quality Requirements and Associated Steam Quality for Industrial/Commercial and Institutional Boilers



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Boiler Water Quality Requirements and Associated Steam Quality for Industrial/Commercial and Institutional Boilers

2005

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INTRODUCTION

The purpose of this publication is to acquaint engineers, purchasers and operators of industrial, commercial and institutional (ICI) boilers with ABMA's judgment as to the relationship between boiler water quality and boiler performance. This document is published for general guidance as a supplement to detailed operating manuals supplied by the equipment manufacturers. It should also be noted that the information presented is directed to steel boiler designs, as opposed to cast iron sectional or copper finned tube boilers. Furthermore Utility Boilers and Combined Cycle Boilers, which require extremely close control of water quality and steam purity, are not the topic of this document.

This new document combines two previous ABMA Guideline documents, namely “Boiler Water Requirements and Associated Steam Purity for Commercial Boilers” (1998), and “Boiler Water Limits and Achievable Steam Purity for Watertube Boilers”, (1995).

The document discusses the effect of various feedwater and condensate systems on the boiler operation. It also provides information on boiler water and steam testing as well as system care and maintenance.

It is recognized that specific boiler usage and water treatment will vary and may require values different from these recommendations. Boiler users therefore, need to define limits, equipment and operating parameters for their particular application.

These recommendations are for information only. Everyone is free to accept or reject the conclusions of these suggestions as their own judgment warrants in all aspects of the conduct of their business.

The ABMA does not represent or warrant that any level of steam purity depicted will be achieved by any particular boiler or boilers.

BACKGROUND

The American Boiler Manufacturers Association (ABMA) was established in 1888 as an association of commercial, industrial and utility boiler manufacturers and manufacturers of fuel burning systems.

In 1939, recognizing the need for information on boiler water and steam conditions, the association published boiler water conditions and steam purity recommendations. This work was reaffirmed and published in 1942, 1947 and 1954. A major revision was published in 1958 and reaffirmed in 1964. Since that time, there has been significant improvement in water treatment and the analytical techniques for measuring water and steam purity. In addition newer and more sophisticated plant designs require improved water and steam purity. Due to these developments and the fact that many users were unacquainted with the earlier work, the association recognized the need to update and republish these recommendations in 1982. That version represented significant change and was intended to reflect the current state of the art for steam generator water requirements. The Watertube version was further updated in 1995 to reflect more rigorous steam purity requirements for modern turbines and other applications requiring exceptionally high steam purity. The most recent version of the commercial boiler document was published in 1998. This latest combined version of the two water quality documents represents an updating to reflect current requirements for steam purity and water quality, particularly in view of the current interest in combined heat and power systems. The various product and technical groups within ABMA have reviewed this revised document prior to its 2005 republishing.

SAFETY PRECAUTIONS AND WARNINGS

1. Before commencing operations, follow the Boiler Manufacturers Installation and Start-Up Checklist, or if this is not available, the Installation and Start-up Checklist on page 17.
2. When dissolving chemicals, the following should be observed:
 - (a) Use of suitable face mask, goggles, protective gloves and garments is required when handling or mixing caustic chemicals.
 - (b) Do not permit the dry chemicals or solution to come in contact with skin or clothing.
 - (c) Always follow the safety precautions on the container's labeling.
 - (d) Warm (80 to 100°F) water should be put into a suitable container.
 - (e) Slowly introduce dry chemical into water, stirring at all times until the chemical is completely dissolved.
 - (f) The chemical must be added slowly and in small amounts to prevent excessive heat and turbulence.
3. Boil out under pressure is not recommended for the class of boilers covered by this document. If units must be boiled out under pressure competent supervision must be provided.
4. If the boiler is not to be operated within 24 hours after boil out see the requirements of Chapter V on Lay-Up.
5. In existing systems the gradual introductions of filming amines is recommended to avoid the rapid removal of corrosion products. Fast removal of rust will cause plugging of traps and strainers (see page 30).
6. Boilers laid up dry shall be tagged with information to indicate the unit must not be operated until moisture-absorbing chemicals are removed and the boiler refilled (see also Chapter V).
7. The use of nitrogen for blanketing is recommended in many of the lay-up procedures. Nitrogen will not support life; therefore, it is essential that proper precautions be taken before such equipment is entered for inspection or other purposes. These precautions shall include disconnecting of the nitrogen supply line, thorough purging and venting of the equipment with air and testing for oxygen levels inside the equipment. Appropriate caution signs shall be posted around the equipment to alert all personnel that nitrogen blanketing is in use.
8. Obtain **MATERIAL SAFETY DATA SHEETS** from the supplier for **ALL CHEMICALS USED** for water conditioning, cleaning and/or lay-up. Read and follow the recommended handling procedures and precautions. Be aware of any potential health hazards from the chemicals being used.

CHAPTER 1

INSTALLATION AND START-UP

PREFACE

Before an attempt is made to place a boiler into operation, the person responsible or in charge of the boiler room should be familiar with this section.

Perhaps the most important part of start-up is the assurance of proper equipment for pretreatment (external treatment) of any make-up either for steam or hot water. A pretreatment system must be operational before any attempt is made to start a boiler.

One should ascertain if the installation is permanent, will be utilized for temporary heat, or if additional segments will be cut in at later construction schedules. This information should be properly noted and schedules set, which will take into account any changes to the pretreatment program.

Following the recommendations in this section should provide the boiler owner with many years of trouble free operation.

INSTALLATION AND START -UP

Before a boiler is placed into operation, it is important that the system and its components be checked for completeness and that operators have an understanding of component and system operation.

Operating Manuals

All manufacturers of boilers supply operating instruction manuals with their equipment. It is important that the operating personnel carefully read and understand the contents of the manual and follow the procedures in the manual. Particular attention should be given to those sections pertaining to the safety precautions.

Manuals for other equipment in the boiler room should be available and understood.

Pre-start System & Component Checkout

After reviewing the operating manual, it is recommended that the boiler and system be checked for completeness of installation before any activation of the boiler. The following procedure should be observed:

1. The unit should be thoroughly examined on the waterside and the fireside to make sure that no foreign material is present.

2. All piping on the boiler, such as blowdown/drain piping, steam/water system piping, feedwater piping, should be checked to assure that the piping has been properly installed so that there is no danger to any individual. Items such as gages, gage glasses, and controls should be checked for any evidence of damage or breaking either due to shipment, or working around the equipment after it has been placed in position.
3. Electrical equipment, such as motors, should be operated wherever possible to assure proper rotation of items such as pumps, blowers, and air compressors. Items such as solenoid valves, interlocks, motorized valves, and limit switches should be checked wherever possible to assure they are operating properly.
4. All fuel lines should be internally cleaned and checked per the equipment manufacturers and local code requirements.
5. Ventilation and combustion air supply should be as recommended by local authorities and the equipment manufacturer.
6. For steam boilers, pretreatment and water treating equipment should be checked for its function and proper piping connections; refer to chapter on Feedwater Systems (see page 20).
7. For hot water boilers refer to section "Make-up for Hot Water Boilers" for further elaboration on system checkout (see page 19).
8. System piping should be verified for completeness. Refer to section "Temporary Use" for further comment (see page 18).

When the system has been checked the boiler and piping are now ready for boil out or clean out.

Boil Out of New Unit

The internal surfaces of a newly installed boiler will have oil, grease or other protective coatings used in manufacturing. Such coatings must be removed since these coatings lower the heat transfer rate and could lead to overheating of a tube and reduce unit operating efficiency. However, before boiling out procedures may begin, the burner should be ready for firing. The operator must be familiar with the procedure outlined in the boiler operating instruction manual.

Your water consultant or water treating company will be able to recommend a cleaning or boil out procedure. In the event such service is unavailable or as yet not selected, the following is suggested.

Suggested procedure for boil out prior to initial operation:

1. Trisodium phosphate and caustic soda are the suggested chemicals for cleaning of newly installed boilers. The quantities will vary according to conditions, but an amount of

one pound of each chemical per 50 gallons of water is suggested. Refer to boiler manufacturer's manual for boiler water capacity.

2. When dissolving chemicals, the following should be observed:

- (a) Use of suitable facemask, goggles, protective gloves and garments is required when handling or mixing caustic chemicals.
- (b) Do not permit the dry chemical or solution to come in contact with skin or clothing.
- (c) Always follow the safety precautions on the container's labeling, and be familiar with the contents of the Material Safety Data Sheets.
- (d) Warm (80 to 100°F) water should be put into a suitable container.
- (e) Slowly introduce the dry chemical into the water, stirring at all times until the chemical is completely dissolved.
- (f) The chemical must be added slowly and in small amounts to prevent excessive heat and turbulence.

3. Before introducing the solution into the boiler, an overflow pipe should be attached to one of the top boiler openings and routed to a safe point of discharge.

CAUTION: Boiling out under pressure is not recommended for this class of boiler. If the units must be boiled out under pressure competent supervision must be provided.

4. Water relief valves and steam safety valves must be removed before adding the boil out solution so that neither the solution nor surface contaminants will settle upon the valve seats. Use care in removing and reinstalling the valves.

5. All valves in the piping to or from the system must be closed to prevent the boil out solution from getting into the system.

6. Gage glasses must be protected from contact with the boil out chemicals during procedure.

7. Fill pressure vessel with clean water until top of the tubes in a firetube/firebox boiler are covered or in a watertube type unit the tube openings in the upper drum are covered. Add the cleaning solution and then fill to the top of the pressure vessel. The temperature of the water used in this initial fill should be at ambient temperature and softened.

8. After filling, the boiler should then be fired intermittently at a low rate sufficient to hold solution just at the boiling point. Boil the water for at least five hours. Do not produce steam pressure.

9. After the five-hour boil, begin to add a small amount of fresh water to create a slight overflow to carry off surface impurities. Continue boil and overflow until water clears. When water clears, shut burner off.

10. Let the boiler cool to 120°F or less, and then drain using caution that the water is discharged with safety.
11. Remove handhole covers and/or wash out opening and wash the waterside surfaces thoroughly using a high pressure water stream.
12. Inspect surfaces and if not clean, repeat the boil out.
13. After boil out, close all openings and reinstall safety or relief valves, gage glasses and other components. Fill the boiler with ambient treated water and fire unit at low fire until water temperature of at least 180°F is reached to drive off any dissolved gases.
14. Boiler is now ready for operation. CAUTION: If boiler is not to be operated within 24 hours see section on lay-up.

System Clean Out

Many clean boilers have been ruined with system contaminants such as pipe dope, cutting oil, metal shavings or chips and other debris associated with installation. If these contaminants are not removed, the debris will find its way back to the boiler.

Steam Systems

For steam systems, the boiler will need to be connected to the header utilizing the steam to purge the piping and push the debris out of the system. However, at this time, all condensate must be wasted until it runs clear and a water analysis indicates that it is free of contaminants. Steam trap strainers should be periodically opened and cleaned of any accumulation of debris.

During this period of system clean out, the make-up water should be properly treated and preheated. After the clean out, the condensate system must be reconnected.

For old or existing steam systems, the installation process may have jarred debris loose. After boil out of the new boiler, the condensate should be wasted until it is within proper guidelines. Check all steam trap strainers to assure their cleanliness.

GENERAL STEAM BOILER PIPING DIAGRAM

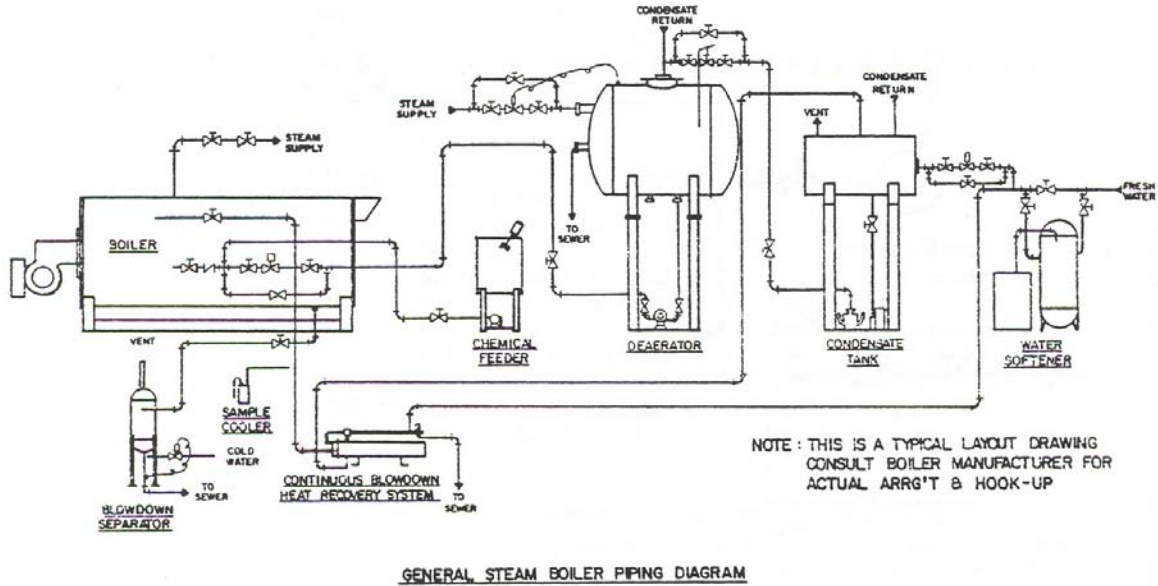


FIGURE 1

WATER BOILER PIPING DIAGRAM

This is a general arrangement diagram of components that make up a water boiler piping system. Follow the boiler manufacturer's recommendations as to location and size of the piping components. Care should be taken to follow their recommendations on piping and operation in order to prevent thermal shock to the boiler.

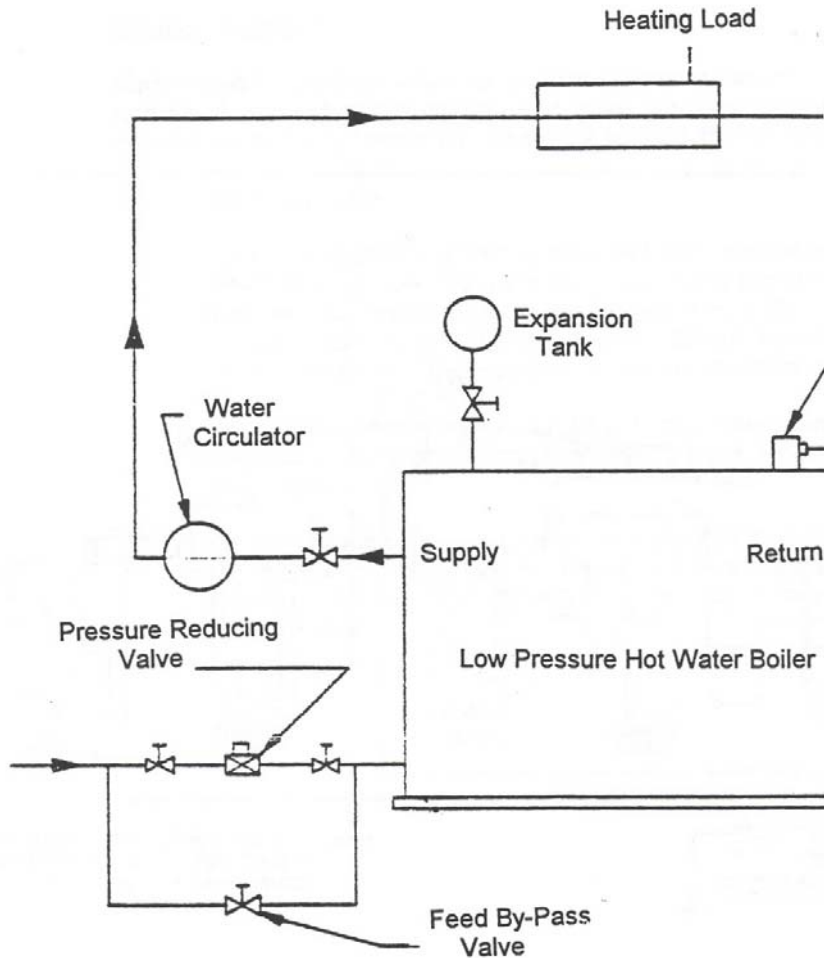


FIGURE 2

Hot Water Systems

One important phase in completing hot water heating installations, which is too often neglected, is proper cleaning of the system. The system is sometimes drained for changes and adjustments but never actually cleaned.

No matter how carefully a system is installed, certain extraneous materials do find their way inadvertently into the system during construction. Pipe dope, thread cutting oil, soldering flux, rust preventatives, slushing compounds, core sand, welding slag and dirt, sand, gravel or clays from the job site are usually found. Although the proportions of these contaminants may be small, there are sufficient quantities to break down chemically during the operation of the system causing gas formation and acidic system water.

Hot water systems must operate with a pH above 8.5. A system that has a pH below 8.5 will usually develop the following problems:

1. Gas formation (air trouble)
2. Pump seal and gland problems
3. Air vents sticking and leaking
4. Frequent relief valve operating
5. Piping leaks at joints

Once any of these conditions exist, the problems continue until corrected by cleaning. Many times, because of the gas formation, automatic air vents are added throughout the system to attempt a cure. The promiscuous use of automatic vents can defeat the function of the air elimination system. In a normal system, the small quantities of air finding their way to the system and piping must be returned to the expansion tank to maintain the balance between the air cushion and the water volume. Note that when a bladder-type expansion tank is used the manufacturer's recommendations should be followed with regard to the venting of air.

If system deterioration is permitted, leaks develop and water losses increase. This can cause serious damage to the boiler. Therefore, it is necessary to have a closed system that is clean, water tight and properly treated with a pH above 8.5.

Arrangements for Flushing Hot Water Heating Systems

Much of the dirt and contamination in a new hot water system can be flushed out prior to chemical cleaning of the system. This is accomplished (see figure 3 for flushing arrangement piping on following page) by first flushing the system to waste with clear water followed by a chemical wash.

The boiler and circulating pump are isolated with valves. City water is allowed to flush through successive zones of the system to waste, carrying chips, dirt, pipe joint compound, etc., with it. This is followed by a chemical flush. Removal of pipe chips and other debris before opening the isolating valves to the boiler and pump will help to protect this equipment from damage by this debris.

After this flushing process is complete the usual cleaning procedure is accomplished.

CAUTION. If one zone is flushed and cleaned before other zones are completed or connected, this process should be repeated on completion of additional zones loops or sections of piping.

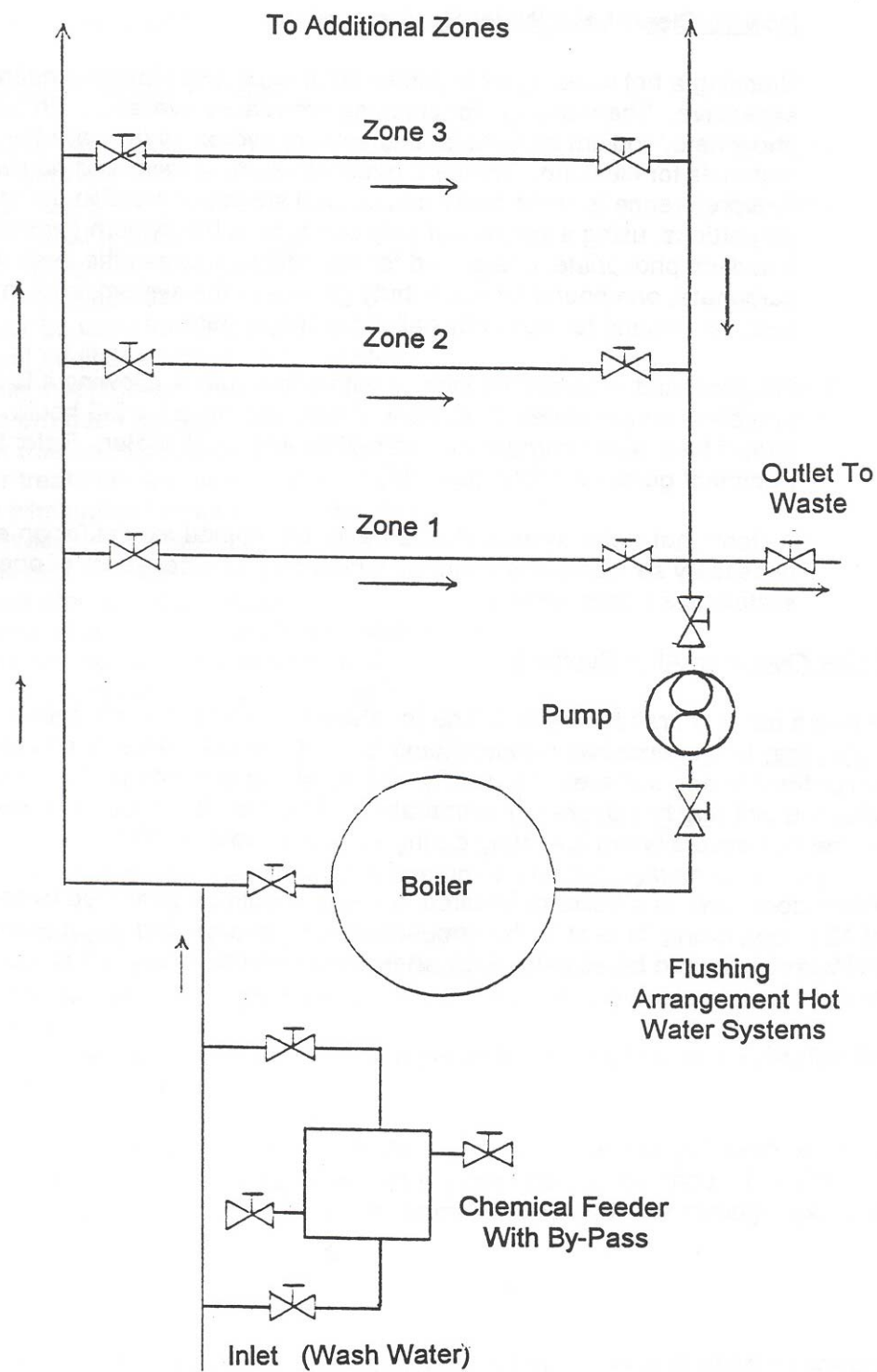


FIGURE 3

How to Clean a Hot Water Heating System

Cleaning a hot water system (either steel or copper piping) is neither difficult nor expensive. The materials for cleaning are readily available. Trisodium phosphate, sodium carbonate, and sodium hydroxide (lye) are the most common materials for cleaning. They are available at most paint and hardware stores. The preference is in the order named and should be used in the following proportions, using a solution of only one type in the system (including boiler): Trisodium phosphate, one pound for each fifty gallons in the system; sodium carbonate, one pound for each thirty gallons in the system; sodium hydroxide (lye), one pound for each fifty gallons in the system.

Fill, vent, and circulate the system with this solution, allowing it to reach design-operating temperatures if possible. After circulating for 2-3 hours, the system should be drained completely and refilled with fresh water. Refer to the water treatment guidelines (see page 23).

A clean, hot water system should never be drained except for an emergency or necessary servicing of equipment which may be after years of operation. A clean system is a better system.

Boiler Operation after Cleaning

When a boiler is fired for the first time (or started after repairs or inspections), vapor and water may be observed as a white plume in the stack discharge or as condensate on the boiler fireside and surfaces. Generally, this condition is condensation that will disappear after the unit reaches operating temperature. This should not be confused with the stack plume that occurs when operating during extremely cold weather.

When cool down of a boiler is required, the unit should be permitted to cool over a period of 12 hours, losing its heat to the atmosphere. Forced cooling is not recommended and will possibly loosen tubes in the tube sheet or cause other damage to the pressure parts

Prior to start-up of the boiler follow the Installation and Start-up Checklist.

Installation & Start-Up Checklist

Have equipment operating manuals been received?	By whom
The manuals are located where?	
Manuals read & understand?	By whom
Boiler installed properly?	
System piping installed properly?	
All zones completed?	
Will boiler be used for temporary heat?	
When will additional zones be connected?	
Has boiler been boiled out?	
Has system been cleaned properly?	By whom

Is water treatment equipment installed?
Is water treatment equipment operational?
Has air elimination for hot water boiler been assured?
Is fuel available for start-up?
Who will perform start-up?
When will start-up be performed?
Has water treatment program been established?
Who is responsible for water treatment?
Have boiler operating logs been set up?

By whom

Checked and verified by: _____

Date: _____

During operation the following may indicate unsatisfactory system water conditions.

1. Obviously discolored, murky, dirty water.
2. Air binding of the systems is caused by accumulation of gases at high points. These gases may ignite and burn with an almost invisible bluish flame when vented.
- 3 A pH or alkalinity test that gives a pH less than 8.5 (below 7 indicates the water in the system is acidic).

The condition of the water can be quickly tested with universal pH paper, which is used in the same manner as litmus paper except it gives specific readings. The pH paper is inexpensive and obtainable from any chemical supply house or through your local druggist.

Temporary Use

A boiler is often utilized in new construction to assist in curing of building components or for temporary heat for the construction crew, or for other purposes during the construction period. If precautions are not taken during this time to protect the boiler, a great deal of damage can occur before the ultimate owner takes over the building. It is the mutual responsibility of the boiler owner and the installing contractor to consider the effect of temporary usage on the boiler warranty. The following should be observed to assure boiler longevity.

Operator Skills/Responsibilities

During the temporary use period a single individual must be assigned the responsibility for the care and operation of the boiler. This person's responsibilities must include but are not limited to:

- Knowledge of burner/boiler operation.

- Possession and understanding of operating instruction manuals.
- Assurance that the boiler is fed treated make-up water at all times.
- Assurance that a hot water system has been flushed properly.
- Operation to maintain at least 170°F operating temperature, or the minimum operating temperature as defined by the boiler manufacturer, for hot water units
- Assurance that the external feedwater treatment equipment is installed and operating.
- Notification to the manufacturer to provide services if the boiler was purchased with factory start-up.
- Adherence to all of the start-up procedures noted earlier in this section.
- Consideration of warranty if the boiler is used for temporary use without following recommended start-up guidelines.

MAKE UP FOR HOT WATER BOILERS

It is important to recognize that hot water systems and boilers will require some amount of raw water make-up. This make-up may be due to leaking pump seals, equipment leaks, piping leaks, drain down for inspection or system repairs, weeping relief valves, improper expansion tank operation and various other causes for leaks.

Raw make-up introduced into hot water boilers requires that the water be properly treated for dissolved oxygen and hardness. These are the two basic causes of hot water boiler failures. One should also note how much make-up is being fed into the system.

A recommendation for a hot water make-up system is illustrated in the sketch on page 16. Its use in new or existing installations will help the boiler operator recognize system leaks and assist in the proper water treatment guidelines.

CHEMICAL AND MECHANICAL CLEANING

Mechanical cleaning of boilers is an inherently safer method of removing scale than acid cleaning. This is because there is less chance to damage the boiler metal. However, the boiler will be out of service for a longer period. Mechanical devices used to remove scale include high pressure water jets, wire brushes, cutters or turbines and rattlers.

Chemical cleaning is a rapid means of removing scale. However, the boiler tubes can be severely damaged if proper care is not taken. Accordingly, it is recommended that firms who specialize in chemical cleaning be retained for this type of work. If a boiler is chemically cleaned, we recommend that all manholes and handholes be opened after the final wash. The seating surfaces should be flushed with water, and new gaskets installed. Failure to do this may permit serious damage to occur. This is because the cleaning agents can be retained in crevices, which are not reached by the final washing solution. When the boiler is returned to service without replacing the gaskets, severe corrosion can occur and eventually cause leakage of boiler water.

CHAPTER II

FEEDWATER SYSTEMS

FEEDWATER SYSTEM COMPONENTS

A feedwater system may include one or several components piped together to provide a method of introducing treated feedwater into a boiler.

A reliable feedwater treatment consultant should be contracted to analyze the water and recommend a proper water chemistry program to prevent:

- Corrosion
- Scale forming deposits
- Carryover
- The required level of steam purity

In the absence of manufacturer's instructions or those of a feedwater treatment consultant, the guidelines shown in Table 1 or Table 2 may be used as a reference.

Components which could be included in a feedwater system are:

Softeners

Softeners are required where natural hardness exists in ground water. This hardness consists of calcium and magnesium compounds, which are relatively insoluble in water and tend to precipitate out causing scale and deposit problems.

Levels of hardness, maximum flow rates, hours of operation, and amount of make-up water are needed to correctly size softening equipment.

Dealkalizers

Dealkalization is a process to reduce the boiler water alkalinity, as an aid in reducing the possibility of corrosion due to carbonic acid attacking the condensate system. The use of a dealkalizer usually requires the addition of a sodium hydroxide (caustic soda) injection system for pH adjustment.

Deaerators

Deaerators mechanically remove oxygen and carbon dioxide found in most raw water. These gases are removed from the raw water by the use of steam, which increases the water temperature, and by various mechanical means, which break up the water particles. The deaerator may be one of three types:

- Tray deaerator
- Spray deaerator
- Packed column deaerator

Condensate Receiver (Hot Wells)

Condensate receivers are required in a system to provide a collection and storage point for returning condensate.

In addition to collecting returning water, the receiver provides:

- A point at which make-up water can be introduced into the system.
- A point at which heat can be added to the make-up water so that cold water is not fed into the boiler. The heating process will also reduce the oxygen level in the make-up but this is not as effective as a deaerator.

Demineralizer

Demineralization is a method of reducing solids in raw water by ion exchange. It is normally used in boiler systems above 300 psig pressure.

Reverse Osmosis Equipment

Reverse osmosis is a method of reducing the dissolved solids in raw water by the use of a semi-permeable membrane. It is normally used in boiler systems operating above 300 psig pressure.

Internal Treatment Equipment

Internal treatment equipment is used to introduce any chemical treatment, which may be necessary for good water chemistry. The type of equipment required will depend upon the condition of the raw water. Equipment selection, chemical selection and the injection point(s) of the chemicals should be made by a qualified chemical treatment firm.

Types of chemical feed equipment available are:

- Intermittent-shot feeders
- Proportioning feeders
- Injection pump systems which may include storage tank and agitator

Filters

Required to remove sand, gravel, mud and other solid matter where physical rather than chemical impurities are found in raw water.

INSTALLATION OF CHEMICAL TREATMENT EQUIPMENT

Installation of a chemical treatment system should be in accordance with recommendations of the boiler manufacturer and chemical consultant.

Maintenance

Maintenance procedures recommended by the feedwater system component manufacturers should be followed. Do not expect the equipment to do more than it was designed to do.