OPERATIONS & MAINTENANCE MANUAL

Prepared by: Cleaver-Brooks Engineered Boiler Systems

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I. COMMENTARY

A. Foreword

This instruction manual is furnished to assist you in the operation and care of your Cleaver-Brooks equipment. Some of the instructions are general and should be interpreted and applied with due consideration for the requirements of your particular operating conditions. They should supplement and not replace the experience and judgment of your operators upon whom sole responsibility for successful and safe operation exists. For specific information relating to sub-vendor supplied equipment, refer to the appropriate sub-vendor literature.

The service of a Cleaver-Brooks field service technician is usually furnished but is provided only if called for in the contract between the purchaser and Cleaver-Brooks should the customer desire the presence of a service technician, such service can be provided at a nominal per diem charge and will be provided upon the receipt of the purchaser's order requesting such service.

When the service of a Cleaver-Brooks technician is provided for the customer, it is for the purpose of aiding and training of the customer's personnel and not to replace them or to assume any of their duties. It should be understood that responsibility for operation rests solely with the customer's operators and Cleaver-Brooks assumes no responsibility for the customer's operator's failure to properly perform their respective duties. The presence of a Cleaver-Brooks service technician at the customer's location in no way relieves the customer's personnel of any of their responsibilities.

This instruction manual is provided to supply general and specific information on the installation, operation, and maintenance of this boiler system. However, not every contingency of installation, operation, and maintenance can be covered in any manual. Therefore, the owners operating and maintenance personnel should also be guided by generally accepted industry practices in the installation, operation, and maintenance of these boiler systems.

The contents of this instruction book describe and illustrate the installation, operation, and maintenance of the equipment furnished with the contract for which it is issued.

No equipment can remain in good operating condition if it is not inspected regularly and repaired and adjusted as required. For this reason, we recommend the appointment of a competent operator and/or maintenance technician to take direct charge of this equipment and to ensure that it receives proper attention at all times.

This instruction book should be given to the operators/maintenance personnel who will have charge of the operation and/or maintenance of the equipment.

This manual is not intended to cover all possible variations in operation or to provide for specific operating challenges that may arise. Should additional information be required, Cleaver-Brooks or its representative should be contacted.

No amount of written instructions can replace intelligent thinking and reasoning on the part of the operators. This manual is not intended to relieve the operating personnel from their responsibility for the proper operation of the equipment. No attempt should be made to operate the equipment until the principals of operation and all of the components are thoroughly understood. Two important prerequisites to good operation are thorough understanding and an interest in the equipment.

Cleaver-Brooks engineers and service personnel do not carry local operator's licenses and, therefore, cannot relieve the customer's operators of their responsibilities with regard to local license and insurance company regulations.

COMMENTARY

A. Foreword – Cont'd

Before the boiler can be started up, Cleaver-Brooks representatives must be assured that the customer is fully insured against equipment failures or operational hazards. See "Pre-Start Up Report" for a list of items to be completed prior to start up.

The customer shall be responsible for complying with Labor Union demands, which may prevail during the start up, operation, or any work performed by Cleaver-Brooks personnel.

It is the responsibility of the owner to train and advise their personnel, as well as contractor personnel, regarding all aspects of the owner's safety requirements.

Cleaver-Brooks equipment is designed and engineered to provide extended and reliable service. The electrical and mechanical devices supplied are of the highest quality and selected because of excellent past performance. Although these components afford a high degree of protection and safety, operation of equipment is not to be considered free from all dangers and hazards inherent in handling and firing combustible fuels. Therefore, proper operating techniques and maintenance procedures must be performed at all times. "Automatic" features included do not relieve operators of any responsibility; they merely free them from repetitions and provide more time for improving performance.

Because of local, state, or other applicable codes, there are numerous electric and safety devices, which vary considerably due to customer requirements and specific jurisdictions. Controls function satisfactorily for long periods of time and experience shows that some operators become lax in their scheduled tests and recordings, assuming normal operation will continue indefinitely. Malfunctions resulting in damage and economic loss can normally be traced to careless omissions regarding routine tests and recording of data.

It is recommended that a boiler log be maintained. Recording of readings and maintenance activities at scheduled times will be valuable in assisting adjustments, corrections, calibrations and repairs. Better knowledge and understanding of equipment will develop operator interest and attention to performance and log history. Periodic review of log records will assist operators in perfecting overall operation and will show areas requiring attention or corrections. Most instances of boiler damage result from operating the boiler at low water conditions. Operators must routinely check water levels by directly observing the gage glasses and by developing good testing procedures. All connecting piping and liquid level indicators and controls should be routinely inspected internally to assure free flow of water to all devices.

The waterside condition of the pressure vessel is extremely important. Waterside surfaces require frequent inspection to check for sludge, scale/hot spots, erosion and corrosion. The services of a qualified and competent water chemistry technician are a prerequisite to good waterside control and preventative maintenance.

The operation of this equipment by the owner's operating personnel must comply with specific regulations of the insurer and/or other jurisdictional authorities. In the event of a conflict between these regulations and the instructions contained herein, please contact Cleaver-Brooks representatives before proceeding.

Warning!
Do not allow anyone but fully trained and authorized personnel who fully understand all applicable sections of this manual and other specific sub-sections to operate, service, or repair this equipment.
Failure to follow all applicable warnings and instructions may result in severe personnel injury, fatalities or equipment damage.

B. Consultation

If you need consultation to solve a problem, you may contact either your local Cleaver-Brooks representative, Cleaver-Brooks Service department at (402) 434-2000 (8:00 AM to 4:30 PM CST) or the Engineered Boiler Burner Group Service Manager at (514) 329-6547 (8:00 AM to 4:30 PM EST), Monday through Friday (except holidays).

Please have the following information when you call:

1. All Cleaver-Brooks drawings that relate to your problem. Please familiarize yourself with the equipment and question(s) before calling and provide a boiler serial number and specific drawing number(s).
2. A brief written description of the problem.
3. The nameplate data from your boiler.
4. A purchase order number in the event parts or a service call is required.
5. Shipping address. Air freight is available if required.
6. A telephone number, fax or e-mail address where we can contact you if we have to call back or provide documentation.

Cleaver-Brooks is interested in supplying you with any replacement parts for the equipment it has supplied. Pricing is available upon request.

C. Introduction to Cleaver-Brooks Product Line

A portion of Cleaver-Brooks' production is the manufacture of packaged water tube steam boilers consisting of three types: A, D, and O. These three types are generally discussed in this manual.

The steam generating components of the package are referred to as the pressure parts and consist of (in various arrangements) drums, tubes, and headers. The upper (steam) drum, located at the highest water level, contains internals for water supply, water chemical treatment and control, water level stability, steam separation, etc. The lower (mud) drum is at the lowest point of the pressure parts and contains internals for mud (sludge) removal. The drums are connected by tubes of plain (non-finned) type. Tubes that feed water to the lower drum are called downcomers. Tubes having steam/water (two phase) mixtures are called risers. This flow of water in downcomers to the lower drum and through risers to the steam drum is referred to as natural circulation. Natural circulation results from the difference in density between heated water (containing steam bubbles) and unheated water completely in the liquid state. The two-phase (water-steam) mixture has a lower bulk density and seeks to rise. The single phase (completely liquid) water has a higher bulk density and seeks to lower area (mud drum) of the boiler.

The pressure parts consist of one (or two, for an A type boiler) integral superheater(s) when superheated steam is specified. First is the furnace where combustion occurs. Second is the tube (convection) bank where hot gases pass around the tubes. Saturated steam is generated in these first two sections. Third is a convective, radiant, or combination superheater which raises steam temperature above saturation temperature.

COMMENTARY

C. Introduction - Cont'd.

Fuel/Air mixtures ignited in the furnace result in radiant, convective, and conductive heat transfer. The hot gas consisting primarily of carbon dioxide, nitrogen, and water vapor is referred to as the products of combustion. The furnace is surrounded by 5 or 6 water cooled walls consisting of plain (sometimes tangent) or membrane finned tubes backed by refractory, insulations, or ceramic fiber as required by specific design. Heat transfer into furnace tubes is both radiant and convective. This area, consisting of riser tubes, is the primary source of two phase steam/water mixture. The other major source of heat transfer is from hot gases that have exited the furnace into the tube (convection) bank. Gas exiting the tube bank, referred to as flue gas, may pass through another heat exchanger such as an economizer, or go directly to a stack prior to entering the atmosphere. The third form of heat, conductive, is that which escapes the envelope and is lost to the surrounding environment.

There are two distinct and separate sides of the pressure parts. The outside, where combustion and hot gases exist is referred to as the gas side. The inside, where water and steam exist is called the water side. If the two sides ever meet (it is called a leak) and will be the result of incorrect operation or inadequate maintenance. This instruction manual provides the owner with guidelines for correct operation and care of the equipment. Another excellent source addressing specific questions is Recommended Guidelines for the Care of Power Boilers, ASME Section VII. This publication is available from The American Society of Mechanical Engineers, 345 East 7th Street, New York, NY 10017.

II. BOILER AND APPURTENANCES

A. General Description

The Cleaver-Brooks packaged water tube boiler is a complete steam generating system. It is a two pass design consisting of a furnace subjected to radiant heat of combustion and hot gases that travel the length of the furnace, then make one 180° turn into the second pass convection section. The gases exit the boiler at the flue gas outlet.

To more fully understand the term "packaged", operators should familiarize themselves with terms and descriptions of equipment that constitute the package. In addition to the boiler, briefly discussed in the introduction and above, are the following:

Burner Assembly Located in the approximate center of the furnace front wall. It is the device contained in a windbox which mixes fuel and air, and injects and ignites the mixture to produce heat. Refer to the burner section for complete details.

Forced Draft Fan & Drive This device, through controlling air flow, provides the proper amount of air required to support combustion of the fuel. The fan provides positive pressure from its discharge through all passages of flow to where flue gas enters the stack or other exhaust equipment. It may be mounted on the burner assembly or separately floor mounted. The motor may be directly connected to the fan wheel or coupling connected to the fan shaft. Fan shaft may incorporate housing mounted bearings or independent pedestal type bearings. The fan may include inlet vortex or outlet damper air control, inlet silencer, and connecting ductwork from fan to windbox. Refer to the fan section (or burner) for complete details.

Water Column and Attachments: The gauge glass is used to visually determine the water level in the boiler steam drum. This device is one of the most important accessories used for safe boiler operation. Therefore, it should be well lighted for visibility and checked regularly for accuracy. Water level alarms and cutoffs, internal or separate devices, are additional accessories used for safe boiler operation. All of these devices are intended to provide safe boiler operation. To ensure proper operation, they should be blown down each shift or at least daily to remove sediment, deposits, etc.

Feedwater Level Control: This device, sometimes coupled to other controllers, senses fluctuating steam drum water level (and sometimes steam flow and feedwater flow) and operates the feedwater control valve to vary the supply of water to the drum. A constant water level is the intended result.

Non-Return Valve (or Steam Stop-Check): Located directly at the outlet of the steam drum (or superheater, when there is one), it is used to automatically prevent back flow of steam (from other boilers in the system) into this boiler. It can also be manually closed to isolate the boiler from the steam header system.

Steam Drum Vent Valve: Located on the top of the steam drum, it vents air and gas from the pressure parts during startup. It can be used to relieve pressure before opening drum manholes or other pressure part access. It is opened to alleviate a vacuum, created by condensing steam, when unit is cooling.

Chemical Feed Connection: This connection is usually on the steam drum (front or rear) and is piped from the chemical feed pump(s). It introduces chemicals directly into the treated boiler water and its internal stainless steel pipe has multiple fractional holes for proportional distribution.

Safety Valves: These valves are located on top of the steam drum (and at the superheater outlet when a superheater is supplied). They safely relieve steam when the internal pressure exceeds specific set points and close when acceptable pressure is established.

BOILER AND APPURTENANCES

A. General Description - Cont'd.

Continuous Blowdown: A fractional multi-holed pipe extending a specified distance into the steam drum and located below the normal water level where suspended solids are in high concentration. These suspended solids are removed by an adjustable setting flow control (metering) valve. The adjustable flow reduces solids concentrations to predetermined and measurable levels. Without this metering valve, solids concentrations would continue rising to unacceptable levels as steam exits the outlet. This metering flow control valve can be manually adjusted as solids concentrations change.

Bottom Blow-Down Valves: These valves are located at the bottom of the mud (water) drum at burner (and/or) target ends, depending on drum length, and provide the means to dispose of sediment precipitated from evaporating water. Headers (when supplied) may also incorporate blowdown valves.

Sootblowers: When required by fuels fired, sootblowers at front (and/or rear) are installed in the convection section of the boiler. Sootblowers remove soot and ash from tubes, using high pressure steam or air. Operator performance and fuels fired dictate frequency of blowing.

Observation Ports: Located in the target (rear) wall and on the burner they provide a clear view of the burner flame, its shape and color pattern. Rear observation ports may be air cooled. Their slide gate valve design allows lens cleaning while boiler is operating.

B. Installation

It is not within the scope of this manual to provide detailed installation instructions which should be in accordance with specifications of the architect, engineer, or contractor. Good engineering practices must prevail. The following discussion covers areas of general concern.

Installation is generally in accord with certain codes and jurisdictions. Proper authorities should be consulted regarding the permanent installation of the boiler room and its support structure, steam venting both temporary and permanent during tests or emergency conditions, fuel supply piping and storage, electrical services, air supply, other piping such as water, steam, bottom blowoff and drains. All applicable permits, licenses, and insurance for construction, testing, and operation must be obtained, including stack permits if applicable.

When the boiler is received, it should be given a thorough inspection by a competent individual to determine if any damage has occurred during transit. External inspection will indicate any obvious damage. The boiler must be inspected internally as well. Bracing or shoring used to protect burner throat, tile, refractories and insulations during shipment are to be removed and checks made for cracking and loose, broken, or missing tile and refractory. Necessary repairs must be completed prior to proceeding. All boxes and crates should be carefully unpacked and checked against packing slips which will be found with each container. In case of any damage or shortage, the carrier is to be notified immediately, make a written report of all problems, include any photos taken, and file necessary claims.

When the boiler is connected to its auxiliaries, check for allowance of thermal growth of various pressure part connections, such as main steam outlet, mud drum blow-off lines, safety valves and their exhaust piping, drains, etc. Provisions for thermal growth include expansion joints, pipe hangers and rollers, pipe loops, and other means of support. Each connection should not exceed its allowable static load, forces, and moments. Due to potentially severe thermal shock, the mud drum blowoff lines should be piped individually to the blowoff tank/sewer system. All superheater drain lines should be piped independently to blowoff/sewer systems to prevent any potential back flow of condensate into the superheater. Superheater vents should be piped to a visible atmospheric exhaust so that visual assurance of flow by the operator is always seen.

B. Installation - Cont'd.

Electrical wiring, wire size, and necessary conduit, junction boxes, switches, feed boxes, circuit breakers, disconnects, starters, etc. need to be in accordance with applicable codes, installed properly and operable. The same applies to instruments, controls, air requirements and all other auxiliaries.

The forced draft fan must be checked for proper rotation and alignment. Since this is a pressurized system, the fan can be cold run and all flanged connections, joints, casing, etc. can be checked for tightness. The fan damper should be closed enough to create sufficient resistance to prevent the motor circuit breaker from overloading. Structural steel, grouting, base plates, duct work and supports, expansion joints, stacks, platforms and ladders should all be checked for proper installation and fit. This would include auxiliaries such as economizers, deaerators, pumping equipment, burners, control panels, fan inlet silencers, heaters, etc.

Field painting must not cover moving shafts, linkage, valve stems, thermal sensitive devices, name plates, or any component where paint could interfere with the normal operation of devices.

C. Pre-operation

1. Preliminary

The Cleaver-Brooks shop assembled unit has most of the boiler trim mounted in the shop, with the exception of the safety valves, vent valve, and blow-off valves, which are shipped separately for clearance purposes. Certain other trim items may also be disassembled for clearance purposes; however, this material will be boxed and tagged. The general arrangement and/or arrangement assembly drawing of the unit will show where these accessories need to be remounted.

During fabrication, every precaution has been taken to keep foreign matter out of the tubes. It often happens that such items may enter the tubes between the time the boiler was fabricated and the time when it is ready to be operated. In view of this, it is recommended that prior to startup technician's arrival, all the tubes in the unit be inspected and cleaned out by a high pressure air or water hose. The manhole covers in the boiler should be opened and the hose introduced from the top drum through every tube - to be certain that no loose material or debris is lodged in any of the boiler tubes. If it is possible, the hose should be pushed through every furnace tube in particular and through every target wall and boiler tube.

Where a tube turbine has been purchased, this turbine can be run through every tube. One man should measure the length of the tubes (from the steam drum) and ensure that the end of the turbine does not come thru into the mud drum. After running the tube turbine thru each tube (from the steam drum) down to about 2 feet from entering the mud drum, then a man enters the mud drum and pushes the turbine up the tubes to "short punch" the remaining tube length.

C. Pre-operation - Cont'd.

2. Hydrostatic Testing and Inspection

The boiler is constructed in accordance with the ASME Boiler & Pressure Vessel Code, Sec. I and was hydrostatically tested in Cleaver-Brooks' manufacturing facility in accordance with sub-section PG-99 "Hydrostatic Test." Copies of the Manufacturers' Data Reports, signed by the inspector witnessing and evidencing the test, have been forwarded to all jurisdictional bodies as well as to the boiler owner. To be sure that the pressure parts are still tight following shipment and installation, the owner may require a hydrostatic test to be conducted as soon as possible after installation. This test will generally be done under the supervision and witnessed by an authorized inspector who may represent either the state or municipality having jurisdiction or the insurance company covering the installation.

At the option of the inspector, this test may be at 1-1/2 times the design pressure of unit, or at a pressure slightly less than the setting of the lowest safety valve. The latter test will avoid the necessity of blanking or gagging safety valves, removing piping and plugging various pipe openings, removing controls and gauge glass, etc. Under no conditions should the steam drum or superheater safety valves be lifted with water.

Before starting a test, make sure that all foreign material, tools, etc, are removed from the boiler by playing high pressure water into the drums, tubes, nipples and headers. Assure all personnel are out of pressure parts and then install manhole covers, including new gaskets. Depending upon the test pressure, be sure to blank off any part that is not designed to withstand the pressure to be developed. This will include water column, gauge glass, feedwater regulators, steam pressure gauge, pressure controls, etc. Safety valves, in this case, must be blanked or gagged.

All connections on the boiler should be closed with the exception of the vent, pressure gauge, and feed line through which pressure will be applied. A pressure gauge of adequate range should be dead weight calibrated to ensure gauge accuracy. The gauge should be temporarily connected to the steam drum vent valve as shown in Fig. 7.

When the boiler is ready for the test, it should be filled with water of a temperature not less than ambient and in no case less than 70°F nor hotter than 120°F. Care should be taken so that all air is vented while the boiler is being filled.

If a superheater is supplied, fill it first in accordance with the supplemental superheater instructions.

Fill the boiler until water flows from the bleed valve. Close the bleed. Treated boiler feedwater should be used when available.

Apply pressure slowly. The recommended rate of pressure increase is less than 50 psi per minute. Proper control must be maintained so that pressure does not exceed the desired setting. When this test pressure is reached, inspection in accordance with the test objective can begin.

Once 1-1/2 times the design pressure is reached, this pressure shall be properly controlled so the 1-1/2 times design pressure is never exceeded by more than 6 percent. The pressure can often then be reduced to design pressure and the boiler inspected for leaks. Weeping tubes (shows some wetness but no water flow) are not considered leaks and will seal when operating temperature is reached. To avoid invalidation of warranty all leaks should be reported to Cleaver-Brooks prior to making any repairs.

Upon completion of the test, release pressure slowly through a small drain valve. Then fully open vents and drains. Particular care must be given to make sure that parts not normally containing water during operation, such as the superheater or circulating tubes above normal water level are drained free of water.

C. Pre-operation - Cont'd.

If temporary handhole or manhole gaskets were used for the test, they should be replaced with regular service gaskets before readying the unit for operation. Gaskets should *never* be reused. Replace gauge glass if necessary and make sure that gauge glass isolation valves (cocks) are open.

CAUTION!
Remove all blanks or gags from safety valves.

Additional inspection at this time, by the authorized inspector, will determine whether the installation: including piping arrangements, valves, gauges and controls and other equipment on the boiler, meet Code and/or other jurisdictional requirements.

3. Cleaning and boiling out

The primary purpose of initial firing, or boil-out, is to dry and cure the furnace refractory and to remove foreign material from the water side of the pressure parts. In addition, this is the time to inspect the boiler casing for flue gas leaks or other problems that may become apparent.

The drums, before assembly, have been cleaned to remove any oil or foreign material that may have adhered during the fabricating process. The tubes are clean when received from the fabricator but in the bending process a solution is introduced into the tubes to lubricate the tube bending mandrel. When expanding the tubes into the drum, a lubricant is applied to the tube expanders. All these foreign materials can be removed by performing an alkaline boil-out of the pressure parts.

Before the boil-out procedures can begin, the boiler should be ready for firing and the operator must be familiar with the operation of the burner and controls and thoroughly understand all instructions contained in the burner and control sections of this manual. The Pre-Start-Up Report in this manual must be filled out, signed and given to the boiler start-up technical supervisor.

CAUTION!
Always fill the boiler with water at a temperature 25-50°F higher than the ambient metal temperature of the boiler pressure parts.

If water colder than 70°F is to be used for boil-out and/or startup and initial running, Cleaver-Brooks must be notified prior to proceeding. A temporary water heater, electric or steam coil, should be used if possible. Heating of cold water in the pressure parts must be done slowly. Use of the burner pilot may be considered. Burner operation, even intermittently at low fire, may cause an excessive metal temperature differential between cold water (inside) and hot gases (outside) resulting in damage to pressure parts and voiding the warranty.

When starting up the boiler and putting it into operation, the most important thing, second to no other item to be considered, is water level. It is assumed that the devices for feeding water into the unit are in operation, and it is of the utmost importance that the water level in the unit be carried at approximately half level in the water gauge glass. A drawing of the particular boiler concerned will show where the water level should be carried under normal conditions. A variation of three inches above or below this water level is tolerable, but is not recommended.

C. Pre-operation – Cont'd.

The caustic chemicals used in boil-out require special care, both in liquid and vapor states, to avoid personal injury. The customer is liable for the disposal of all chemical solutions once their use is complete. These solutions can damage drum manway gaskets and water column sight glasses requiring their replacement. Cleaver-Brooks provides replacement gaskets and a tubular sight glass for use during boil-out. This glass has a low pressure rating (250 PSIG max) and care must be taken not to exceed this pressure. The glass must be replaced before the boiler is operated at rated pressure.

4. **Boilout procedure**

The following instructions are to be performed under the supervision of a factory trained representative.

A new boiler must be boiled out with a solution of suitable chemicals to thoroughly cleanse the internal surfaces. Petroleum based products may accumulate during fabrication which could cause foaming, water carryover, and possible equipment damage.

THE PROPER BOIL OUT PROCEDURE MUST BE DETERMINED BY THE COMPANY THAT WILL HANDLE THE CHEMICAL TREATMENT OF THE UNIT. ANY RECOMMENDATIONS FROM THE MANUFACTURER MUST BE INTERPRETED AS BEING MERELY SUGGESTIONS AND IN NO WAY CONSTITUTE A MANDATORY REQUIREMENT.

Prior to commencing the boil out, the following needs to be checked:

a) Boiler drums should be inspected internally and all foreign material removed.
b) To ensure thorough cleaning, all drum internals should be tightly in place and not obstructing tube openings.
c) It is suggested that a temporary gauge glass be installed during the boil-out operation when a prismatic or flat gauge glass is furnished.
d) Fill the boiler with water at or above ambient temperature to a point 2" below the manhole opening in the steam drum.
e) The superheater is to be kept dry (not filled with water) during boil-out.
f) When proper quantities of chemicals have been added, close all steam drum openings.
g) For saturated boilers, fill boiler to normal steaming level (one half glass). For superheated boilers, refer to section III.A.2.
h) Open the steam drum vent valve or, if the boiler is equipped with a superheater, open the superheater outlet vent valve. Recheck the burner, feedwater supply, gauge glass, pressure gauge, and the position of all valves.
i) Set high steam pressure cut out to operating pressure, but not to exceed 150 PSIG.

CAUTION!

All safety devices relative to fuel, water and steam systems must be in operable conditions

j) After the boil-out, inspect the drums and wipe out any sludge or scum that may be present. Then wash out boiler thoroughly with a high pressure hose, using water of approximately 70°F temperature, or ambient. Use a hose on each individual tube including superheater and economizer tubes. The fireside of the boiler should be checked for any unusual conditions.
k) Upon completion of the wash down, inspect the internal surfaces and if not clean, repeat the boil-out.
l) Replace manhole covers and install new manhole gaskets. Replace the gauge glass if necessary. Reinstall the prismatic (or flat) gage glass if boiler is so equipped.

D. System Contamination

Steam and water piping systems connected to the boiler may contain oil, grease or foreign matter. In new systems, the piping usually has an accumulation of oil, grease, weld slag and dirt. Old systems have an additional hazard in that the piping and receivers may be heavily limed and full of scale as the result of improper water treatment.

These impurities must be prevented from entering the boiler. On a steam system, the condensate should be wasted until tests show the elimination of undesirable impurities. During the period that condensate is wasted, attention must be given to the treatment of the water used as make-up, so that an accumulation of unwanted materials or corrosion of drums and tubes does not occur. Follow the advice of your water treating company.

Consult with water treatment companies for recommendations, cleaning compounds and for application procedures.

If oil, dirt and scale accumulations are permitted to get into the boiler, it may be necessary to repeat the boil-out procedure. If this becomes necessary, the same procedure as outlined under boil-out should be followed.

The waterside of the pressure vessel must be kept clean from grease, sludge and foreign material. Such deposits, if present, will not only shorten the life of the pressure vessel and interfere with efficient operation and functioning of control or safety devices, but could cause unnecessary and expensive re-work, repairs and down time.

The pressure vessel waterside should be inspected on a periodic basis. This will reveal true internal conditions and serve as a check against conditions indicated by chemical analysis of the boiler water. Inspection should be made three months after initial starting and at regular 6, 9 or 12 month intervals thereafter. The frequency of further periodic inspections will depend upon the internal conditions found.

If any unwanted conditions are observed, your water consultant or water treating company should be contacted for recommendations.

Any sludge, mud or sediment found will have to be flushed out. The effectiveness of the blowdown practiced on steam boilers will be verified and scheduling or frequency of blowdown may have to be revised. The need for periodic draining or washout will also be indicated.

E. Feedwater System and Treatment

The subject of water supply and treatment is of great importance and it can not be adequately covered in this manual. Maximum effectiveness and long trouble-free life of the pressure vessel are functions of properly treated water. The type and extent of water treatment is determined by the water supply. The services of a reliable boiler water treatment specialist or company should be engaged to analyze the water and prescribe treatment. Their recommendations should be followed rigidly to prevent the presence of unwanted solids and corrosive gases. Failure to do so will result in ever decreasing boiler efficiency as well as shortened useful life.

Objectives of water treatment in general are:

1. Prevention of hard scale deposits or soft sludge type deposits, which impair the rate of heat transfer and can lead to overheated metal and costly down time and repairs.
2. Elimination of corrosive gases, in supply or boiler water.
3. Prevention of intercrystalline cracking or caustic embrittlement of boiler metal.
4. Prevention of carryover and foaming.

The accomplishment of these objectives generally require treatment before and after introduction of water into the boiler.

The selection of pre-treatment processes depends upon water source, chemical characteristics, amount of make-up water needed, plant operating practices, etc. These treating methods include filtering, softening, demineralizing, deaerating and preheating.

After treatment involves the addition of chemicals to the boiler water. This after treatment is required to compensate for any variations in the pre-treatment and pre-boiler system and to assure the ultimate protection of the boiler. Because of the variables involved, no one "boiler compound" can be considered a cure-all, nor is it advisable to experiment with home-made treating methods. Sound recommendations and their employment should be augmented by periodic analysis of the raw water, boiler water and condensate.

The internal or waterside surfaces of the pressure vessel should be inspected with sufficient frequency to determine the presence of any contamination, accumulations of foreign matter, corrosion, and/or pitting. If these conditions are detected, the water consultant or feedwater treatment company should be consulted for advice on corrective action.

It is advisable to have a properly sized water meter installed in the raw water make-up line to accurately determine the amount of raw water admitted to the boiler. This will aid the water treatment program in maintaining proper waterside conditions.

Suggested Water Chemistry Limits
Industrial Watertube, High Duty,
Primary Fuel Fired, Drum Type

Makeup water percentage: Up to 100% of feedwater
Conditions: Includes superheater, turbine drives, or process restriction on steam purity
Saturated steam purity target: See tabulated values below.

Drum Operating Pressure (1) (11)	**Psig 0-300 (MPa) (0-2.07)**	**301-450 (2.08-3.10)**	**451-600 (3.11-4.14)**	**601-750 (4.15-5.17)**	**751-900 (5.18-6.21)**	**901-1000 (6.22-6.89)**	**1001-1500 (6.90-10.34)**	**1501-2000 (10.35-13.79)**
Feedwater (7)								
Dissolved oxygen ppm (mg/l)O_2 - measured before chemical oxygen scavenger addition (8)	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
Total iron ppm (mg/l) Fe	≤ 0.1	≤ 0.05	≤ 0.03	≤ 0.025	≤ 0.02	≤ 0.02	≤ 0.01	≤ 0.01
Total copper ppm (mg/l) Cu	≤ 0.05	≤ 0.025	≤ 0.02	≤ 0.02	≤ 0.015	≤ 0.01	≤ 0.01	≤ 0.01
Total hardness ppm (mg/l)*	≤ 0.3	≤ 0.3	≤ 0.2	≤ 0.2	≤ 0.1	≤ 0.05	ND	ND
pH @ 25°C	8.3-10.0	8.3-10.0	8.3-10.0	8.3-10.0	8.3-10.0	8.8-9.6	8.8-9.6	8.8-9.6
Chemicals for preboiler system protection	NS	NS	NS	NS	NS	VAM	VAM	VAM
Nonvolatile TOC ppm (mg/l) C (6)	< 1	< 1	< 0.5	< 0.5	< 0.5	< 0.2	< 0.2	< 0.2
Oily matter ppm (mg/l)	< 1	< 1	< 0.5	< 0.5	< 0.5	< 0.2	< 0.2	< 0.2
Boiler Water								
Silica ppm (mg/l)	≤ 150	≤ 90	≤ 40	≤ 30	≤ 20	≤ 8	≤ 2	≤ 1
Total alkalinity ppm (mg/l)*	< 700(3)	< 600(3)	< 500(3)	< 200(3)	< 150(3)	< 100(3)	< NS(4)	< NS(4)
Free OH alkalinity ppm (mg/l)* (2)	NS	NS	NS	NS	NS	NS	ND(4)	ND(4)
Specific conductance (12) µmhos/cm (µS/cm) 25°C without neutralization	5400-1100(5)	4600-900(5)	3800-800(5)	1500-300(5)	1200-200(5)	100-200(5)	≤ 150	≤ 80
Total Dissolved Solids in Steam (9)								
TDS (maximum) ppm (mg/l)	1.0-0.2	1.0-0.2	1.0	0.2	0.5-0.1	0.5-0.1	0.1	0.1

* as $CaCO_3$
NS = not specified
ND = not detectable
VAM = Use only volatile alkaline materials upstream of attemperation water source. (10)

Notes to Table:

(1) With local heat fluxes >1.5 x 10^5 Btu/hr/ft^2 (>473.2 kW/m^2), use values for at least the next higher pressure range.
(2) Minimum hydroxide alkalinity concentrations in boilers below 900 psig (6.21 MPa) must be individually specified by a qualified water treatment consultant with regard to silica solubility and other components of internal treatment. See section 6.6 of this document.
(3) Maximum total alkalinity consistent with acceptable steam purity. If necessary, should override conductance as blowdown control parameter. If makeup is demineralized quality water and boiler operates at less that 1000 psig (6.89 MPa) drum pressure, the boiler water conductance should be that in table for 100-1500 psig (6.9-10.34 MPa) range. In this case, the necessary continuous blowdown will usually keep these parameters below the tabulated maximum values. Alkalinity values in excess of 10% of specific conductance values may cause foaming.
(4) Not detectable in these cases refers to free sodium or potassium hydroxide alkalinity. Some small variable amount of total alkalinity will be present and measurable with the assumed congruent or coordinated phosphate-pH control or volatile treatment employed at these high pressure ranges.
(5) Maximum values are often not achievable without exceeding maximum total alkalinity values, especially in boilers below 900 psig (6.21 MPa) with >20% makeup of water whose total alkalinity is >20% of TDS naturally or after pretreatment by lime-soda, or sodium cycle ion exchange softening. Actual permissible conductance values to achieve any desired steam purity must be established for each case by careful steam purity measurements. Relationship between conductance and steam purity is affected by too many variables to allow its reduction to a simple list of tabulated values.
(6) Nonvolatile TOC is that organic carbon not intentionally added as part of the water treatment regime. See Section 6.4 of this document.
(7) Boilers below 900 psig (6.21 MPa) with large furnaces, large steam release space, and internal chelant, polymer, and/or antifoam treatment can sometimes tolerate higher levels of feedwater impurities than those in the table and still achieve adequate deposition control and steam purity. Removal of these

impurities by external pretreatment is always a more positive solution. Alternatives must be evaluated as to practicality and economics in each individual case.

(8) Values in the table assume existence of a deaerator.

(9) Achievable steam purity depends on many variables, including boiler water total alkalinity and specific and specific conductance as well as design of boiler steam drum internals and operating conditions [(Note 5)]. Since boilers in this category require a relatively high degree of steam purity for protection of the superheaters and turbines, more stringent steam purity requirements such as process steam restrictions on individual chemical species or restrictions more stringent than 0.1 ppm (mg/l) TDS turbine steam purity must be addressed specifically.

(10) As a general rule, the requirements for attemperation spray water quality are the same as those for steam purity. In some cases boiler feedwater is suitable; however, frequently additional purification is required. In all cases the spray water should be obtained from a source that is free of deposit forming and corrosive chemicals such as sodium hydroxide, sodium sulfite, sodium phosphate, iron, and copper. The suggested limits for spray water quality are < 30 ppb (µg/l) TDS maximum, < 10 ppb (µg/l) Na maximum, < 20 ppb (µg/l) SiO_2 maximum, and it should be essentially oxygen free.

(11) Low pressure boilers frequently use feedwater that is suitable for use in higher pressure boilers. In these cases the boiler water chemistry limits should be based on the pressure range that is mose consistent with the feedwater quality. See Sections 1 and 6.2 of this document regarding blowdown.

(12) Conversion from ppm (mg/l) TDS values in the ABMA standards [12] used a factor of 0.65. See Section 6.7 of this document.

F. 'ABMA' Statement for Auto Firing

One of the accepted values to the owner of an automatically fired boiler unit is its operation by the use of automatic controls. Such controls reduce the amount of manual labor required, afford a consistently high degree of regulation, and therefore, contribute to the low cost of producing steam.

In order to obtain these advantages, purchasers and users of automatically fired boiler units must recognize that competent supervision and adequate maintenance is required for safe and dependable operation.

The automatic operation of such units does not eliminate the necessity of employing qualified operators.

Manufacturers of automatically fired boiler units do not assume any liability for injury to persons or damage to property which may be attributed to the operation of the equipment.

G. Preparation Before Initial Firing

The operator must be knowledgeable of the boiler, the burner and all controls and components and must be qualified to operate this equipment. The operating conditions of all auxiliary equipment and instrumentation that serves in the firing and feeding of the boiler should be formally checked out. Be sure that auxiliary equipment not supplied by Cleaver-Brooks is of adequate size and pressure to ensure proper operation. Check for proper voltage, fuses and overloads. Check rotation of all motors by momentarily closing the motor starter or relay. Check the reset of all starters and controls having a manual reset feature. To the extent possible, all operating mechanisms, valves, air dampers and drives should be checked for proper operation and freedom from binding. Check the settings of all controls.

Verify fuel supply. Make certain that fuel pressure is sufficient and that gauges are indicating correctly. Properly set any adjustable limit on interlock controls. Pretest them for proper function at set points if feasible.

Before operating a boiler feed pump or an oil supply pump, be sure that all valves in the line are open or properly positioned. Be certain that pump rotation is correct. If in doubt, remove coupling and check motor rotation. Some pumps can be severely damaged by even momentary reverse rotation. Also recheck coupling alignment.

Check out the burner in accordance with procedures given in the burner instruction manual. Safety valves should be inspected externally to see that they are free to operate and that their discharge and drain piping is open to atmosphere and free to expand without imposing stress on the safety valve body. Make sure that any gags used during testing are removed. Ascertain that discharge piping from the safety valves and also from all blowdown vent and drain valves is piped to a SAFE point of discharge, so that emission of hot water or steam cannot possibly cause injury to personnel or damage to property.

Prior to closing drum manholes, make certain that all internal fittings are in place and that no tools, gear or personnel remain inside. Make a final check of the fireside area to make sure no tools, construction gear, debris or personnel are present.

For safety's sake, make a final and complete pre-startup inspection, especially checking for any loose or uncompleted piping or wiring or any other situation that might present a hazard.

H. Filling The Boiler

Check and close the manual blowoff valves, the continuous blowdown valves, the gauge cocks and the water column and gauge glass drain valves.

Open the steam drum vent valve, the water column shutoff valves, if any, the gauge glass shutoff valves and the steam pressure gauge shut-off valve. Open the superheater vent and drain valves - on superheated units.

The boiler should be filled with properly treated feedwater using the bypass feed line. The water should be 25 - 50°F above the metal temperature to prevent excessive temperature stresses that could cause tube leakage. 70°F minimum water temperature is recommended unless ambient is considerably higher. Fill to normal level of half full gauge glass. Fill slowly and vent fully to prevent any pressure buildup from the flashing of hot feed water.

Blow down the water column and gauge glass, making sure that the water level returns to the proper level promptly. The gauge cocks, if supplied, should also be operated to verify water level.

The boiler is supplied with a feedwater controller and control valve. Their purpose is to automatically maintain the proper operating water level when supplied with the appropriate water pressure and flow. The control valve is supplied with a manual bypass for initial fillings or when otherwise necessary.

H. Filling The Boiler – Cont'd.

If the water supply is shut off during operation, the water level may drop 3-4 inches in a matter of minutes. The low water cut-offs will shut the burner off before the water level reaches a dangerously low level. Observe that the cut-offs are working properly and make any required corrections. The water level should be checked often to ensure the feedwater control system is working properly.

CAUTION!
In the remote event that there is no water visible in the gauge glass and the burner is still operating, shut the burner off immediately. Never add water until it has been determined the boiler has not been overheated by the low water condition.

I. Routine Operation

1. Initial Firing

There must be an unrestricted path for air flow from the forced draft fan inlet through the stack and into the atmosphere, excluding any air flow control dampers.

Remove boiler blocking and any debris from the furnace. Small amounts of wood shoring and forms, not easily removed, may be burned during initial firing.

Due to the corrosiveness of boil-out chemicals and the toxicity of their fumes, it is suggested that all steam vent valves be opened and piped to a safe location.

Start the burner following the instructions in the burner operating manual. Make sure that combustion is stable. Check and adjust the burner and its components as outlined in the burner manual.

The firing rate should be manually controlled and held in the low fire position until the boiler is properly warmed. The control circuit may have a low fire control which will prevent the burner from firing in other than the low fire position, until the boiler is sufficiently warm. This control, when supplied, is usually adjusted to cut in at approximately 50 psig.

The boiler should be brought up to temperature and pressure at a slow and carefully controlled rate. Conditions can vary, however, an accepted rate of water temperature rise of 80 to 100°F per hour is acceptable. See Table 1 for temperature/pressure relations.

TABLE 1

Sat. Water/Steam Temp, °F	Drum Pressure, PSIG
212°	0
250°	15.1
300°	52.3
350°	119.9
400°	232.6
450°	407.9
500°	666.1
550°	1030.5

The recommended water temperature rise of 80-100°F per hour applies to cold starts, units that have been off line for 12 or more hours, and startup involving thick walled drums (design pressures exceeding 600 PSIG). Before applying higher firing rates to reduce time to on-line operation, consult Cleaver-Brooks or our local representative.

I. Routine Operation (l. Initial firing) - Cont'd.

As steam pressure rises with the non-return valve closed, expanding water will be indicated by a rise in gauge glass level. It is recommended that periodic blowdown be done to maintain half gauge water level.

If equipped with a superheater, it is imperative that the superheater start-up vent valve be open while the main steam valve is closed. A flow of steam through the superheater is essential for the protection of the tubes. Refer to the superheater section in this manual. Superheater drains and drum vent should be open at this time.

During this period of operation, carefully observe that all components function properly. Be prepared to shut the unit down should a lack of proper operation become evident. Visually observe combustion conditions for proof that gauges, meters and other instrumentation are properly reporting conditions.

Leaks caused by thermal expansion usually appear during initial boiler operation. An inspection should be conducted at this time with particular attention given to the following:

a) Gaskets at manhole covers, piping flanges, and gage glasses may need tightening as well as valve stem packing. If tightening does not seal, shut down and replace gaskets, etc. as needed.
b) Threaded pipe connections may need tightening or replacement.

Close the drum vent and superheater drains when steam pressure reaches 10 to 25 psi. Refer to superheater section for information on its vent and drain valves.

Maintain the normal water level at all times. Maintain the water level by hand feeding or by blowing down as necessary. Too high a level will cause flooding and render the separators ineffective, while too low a level will allow possible overheating tubes. If the water level is not readily apparent, use the gauge cocks (if supplied) and close inspection to determine the level. If the level is not visible, firing should be stopped and the reason for low level determined.

The feedwater control valve should be put into service when operating pressure is reached. The feedwater bypass valve should be closed at this time.

ASME Section I does not require field testing of safety valves. If local jurisdictions require such testing to verify popping and blow-down pressures, they must be popped under steam pressure. NEVER POP SAFETY VALVES WITH WATER. Recommendations of the authorized inspector will determine exact procedure. Suggested method is as follows:

a) Raise high steam pressure cutout setting above highest safety valve set pressure.
b) Bring boiler pressure up to safety valve set pressure and observe relieve pressure to verify correct setting.
c) Shut Burner off.
d) Gag previously popped valve(s).
e) Repeat steps a. through d. until all valves are popped.
f) Reduce high steam pressure cutout to original setting.
g) Refer to safety valve manufacturer's instruction manual if adjustment to set pressure is required. Do not attempt to field change the set point.

I. Routine Operation (1. Initial Firing) - Cont'd.

When boiler pressure has increased to the desired point, the boiler can be cut into service according to good operating practice.

During the early stages of the startup period, after boilout, the drain on the boiler side of the main steam stop valve should be opened. When all condensate is removed, open the non-return (stop check) valve slightly to warm the down stream piping. If the non-return is equipped with a bypass, it may be used for warm-up.

NOTE!
The safe and proper heating of down-stream piping is not Cleaver-Brooks' responsibility. To prevent water slugs, water hammer, and excessive thermal expansion, slow heating and venting steam lines is recommended. The owner is responsible for functioning steam traps, vents, and drains; piping that includes proper supports, expansion joints, and thermal expansion pipe loops.

2. Daily Procedures

Following the instructions contained in the preceding section "initial firing," the boiler is now ready for full time service.

Second to none, in importance, is the regular observation of boiler water level. Proper setting and adjustment of the drum level transmitter and the feedwater flow control valve will assure proper water level. The deaerator, feedwater tank, and feedwater pumping system, as well as chemical feed systems, are to be on line at this time. Proper gauge glass illumination is functioning.

With the boiler having been fired at low fire for at least 30 minutes, and if main steam lines are hot, open the stop valve. Prior to slowly opening the non-return valve, the boiler should be blown down to half gauge glass level. The boiler is now on the main steam header distribution system.

At this time the burner and controls will be calibrated for proper fuel/air ratios across entire firing range and additional indicators, transmitters, allied instrumentation and controls will be adjusted, set, calibrated and placed in service. Refer to specific sections of the manual for instructions.

The information that the operator routinely seeks from a number of sources, listed in their approximate order of importance, are:

a) Water level.
b) Visual observation of the fire through observation ports in burner and on boiler rear (target) wall.
c) Pressure of steam and of feedwater.
d) Temperatures of superheated steam leaving the major subdivisions of the superheater.
e) Drafts or pressures of gases and air entering and leaving the principal sections of the equipment traversed.
f) Boiler-water conditions, including carry-over.
g) Operation or non-operation of feed pumps, fans, fuel-preparation and fuel-burning equipment.
h) Relationship of actual combustion air passing through the furnace to that actually needed, as indicated by flue gas analyses, oxygen determinations, or other means.
i) Temperatures of water, gas, fuel, and air entering and leaving the principal sections of the equipment traversed.
j) Feedwater flow.

k) Fuel flow.

I. Routine Operation (2. Daily Procedures) -Cont'd.

l) Steam flow.
m) Knowledge of what operating functions are interlocked, so that they cannot be performed in an improper sequence.
n) Knowledge of what important operating functions are being performed automatically.

Automatic control is virtually inseparable from instruments. The list of functions, which should be controlled automatically, varies somewhat as the list of instruments varies with the size of the plant, the proficiency of the operators, the type of equipment, and, therefore, with the savings which can be effected. In general, the use of automatic control can be justified in the regulation of all the operating functions that do not require an operator's judgment and that cannot be performed at less total expense by an operator.

The day to day operation, instrument and controls observation, data collection and recording, and care of equipment is a major component of overall on-line maintenance. The goal of proper operation is minimal maintenance, elimination of all but scheduled shut downs, and minimized reasonable supervision.

Proper operation considers as minimum goals:

a) Maximum efficiency of the fuel fired.
b) Proper fuel/air ratios across entire firing range to eliminate external corrosion/erosion, and hot spots on pressure parts.
c) Proper water treatment and control to eliminate corrosion and build-up on internal pressure parts.
d) Minimize sludge and other foreign matter on water/steam side of pressure parts.
e) Eliminate all deposits on superheater surfaces.
f) Minimize foreign material deposits on gas side heating surfaces and particles discharged to atmosphere.
g) No carry-over in the steam harmful to equipment or processes.
h) Maximize productive work by equipment operators.
i) Continual review and improved safety of operators.
j) Continual review and protection of equipment.

3. General

Daily operation should include a check of the burner performance, fuel and atomizing pressures, instruments and controls, and observation of flame color and shape through various ports. Refer to burner and controls sections of this manual for specific instructions. Alertness in recognizing sound changes, unusual noise, changes in instrument readings, leaks, signs of over-heating, etc. create awareness of a developing problem. Awareness leads to prompt corrective action before excessive or hazardous results occur.

a. feedwater regulation and control

The boiler is equipped with a three-element feedwater control system which automatically maintains proper water level when a suitable water supply is available.

Consult technical information from the control system vendor to supplement the information provided in this manual.
Refer to the specific section of this manual for manufacturer literature and instructions for Cleaver-Brooks supplied equipment.

The flow control valve has a three valve isolation and bypass system.

I. Routine Operation (3. General, a. feedwater regulation and control) -Cont'd.

At startup the drum level must be maintained by shutting an isolation valve and controlling drum level using the bypass valve.

When operating pressure has been reached, the system may be placed in auto using supplied controllers. Open both isolation valves and close the bypass valve. The manual/auto controller in manual will open and close the flow control valve at set point from 0-100% open. In auto position the drum level transmitter, adjusted and corrected by any other elements in service will automatically maintain set point drum level.

If proper water level is not maintained, refer to manufacturer's instructions for adjustments and corrections. Please note the drum level controls are part of the same equipment package supplied by the controls contractor. Their literature needs to be referred to as well.

b. water level indication and control

The water level alarm system consists of electrode probes mounted in the water column or a separate body. Three probes and a common are normally furnished. The probes signal or control high water alarm, low water alarm, and low water cut-off. Cut-off shuts down the burner system, alarms are wired to a horn. An additional probe for high water cutoff is also provided. The probes are wired through relays to the burner management system and to other controls when specified.

The need to routinely check water level controls cannot be overemphasized. Most instances of major damage result from low water operation. Blow down the water column or probe container routinely by quickly opening and closing the respective drain valve. Observe the gauge glass for prompt return of water level. To continue normal operation during blowdown, depress and hold pushbutton to bypass the relay circuits. This procedure must be performed daily and preferably on each shift.

CAUTION!
While bypass pushbutton is depressed, there is no automatic safety protection of the boiler for low water conditions

Figure 1 shows the warning plate attached to the boiler. The instructions should become part of the routine procedures.

These controls will function for long periods of time and may result in operator laxness. If any low water device begins to operate erratically or settings (levels) change from previous established norms, repair or replacement is required.

When the boiler is equipped with float type mechanisms, in addition to routine blowdown, the float head should be removed, internals cleaned, and floats checked for proper travel and relay contact on a specific schedule.

Routinely remove pipe plugs from crosses in pipe connecting these devices to be sure they are clean. Remove any obstructions. Check all piping and devices for alignment, plumb and horizontal arrangement.

I. Routine Operation (3. General, b. water level) – Cont'd.

WARNING

Safe operation of your boiler demands periodic inspection and maintenance of all low water cut-off devices. Inspect them at least once a month. Proper operation should be checked frequently by closing feedwater valve with boiler in operation and allowing water level to drop at a normal rate. If controls under test do not cut off burner at proper safe water level or are seen to be in poor physical condition, repair or replace at once. Mud and sediment accumulations in the gauge glass, water column, and auxiliary low water controls should be eliminated by proper blowdown procedure.

Fig. 1 Low Water Cut-Off Plate

c. the water column

In addition to the probes described in the previous section, the water column also contains the equipment to provide the operator with visual knowledge of the water level.

The gauge glass attached to the side of the column is used to visually check the boiler water level. The gauge valves provide a means of isolating the gauge glass in the event of breakage or replacement.

This visual knowledge of the water level is one of the most important guides available to the operator. The importance of frequent observation of the water level cannot be over-emphasized.

Keep the gauge glass clean and properly lighted for good visibility. Refer to the operating and maintenance section of this manual for blowdown test procedures and replacement.

Operate the gauge valves regularly to ensure their being satisfactory for emergency service.

The normal water level in a Cleaver-Brooks watertube boiler is indicated at the midpoint of the gauge glass (glass half full).

The low water alarm probe is usually positioned to be energized should water fall approximately 4" below normal. The alarm signal will alert the operator of this condition.

Should water level fall 5" to approximately 1" visibility in the gauge glass, the low water cut-off probe will be exposed and will act to shut down the burner.

The ASME Boiler and Pressure Vessel Code requires that the lowest visible point of the water glass shall be at least 2" above the lowest permissible water level. This is the point at which there will be no danger of overheating any part of the boiler when operation is at that level.

CAUTION: In the event the burner is firing at any time that water is not visible in the water gauge glass, immediately turn off the burner. **DO NOT TURN ON THE WATER FEED LINE.**

I. Routine Operation (3. General, c. the water column) -Cont'd.

DO NOT LIFT (POP) THE SAFETY VALVE. Let the boiler cool until the drum is at hand touch temperature. Then add water to a height of 1" in the gauge glass. **DO NOT PUT THE BOILER BACK INTO SERVICE UNTIL THE CONDITION RESPONSIBLE FOR THE LOW WATER HAS BEEN IDENTIFIED AND CORRECTED.** Do not attempt to put the boiler back into operation if there is evidence of overheated metal, or even suspected damage, until a thorough inspection and/or repairs have been made.

Clean the water gauge on a regular basis. A weekly frequency is suggested. A check of water level should be made when there is steam pressure in the boiler. Close the lower gauge glass valve, then open the gauge glass drain valve and blow the glass clear. Close the drain valve and open the lower gauge glass valve. Water should return to the gauge glass immediately. If water return is sluggish, leave the lower gauge glass open and close the upper gauge glass valve. Then open the drain valve and allow water to flow until it runs clear. Close the drain valve and repeat the first test with the lower gauge glass valve closed.

If leaks appear around the water gauge glass or fittings, correct the leaks at once. Steam leaks may result in a false water line and may also damage fittings.

The handles on the gauge glass valves must be installed on the valve stems so that their position indicates whether the valve is open or closed. The operating chain on the right hand side of the levers should be snug between levers so that both valves will be closed tight when the chain is pulled from below.

d. blowdown

Boiler water blowdown is the removal of some of the concentrated water from the pressure vessel while it is under pressure. The removed water containing suspended solids and dissolved solids is replaced with relatively pure feedwater so that a lowering of the concentration results.

Solids are brought in with the feedwater even though this water is treated prior to use through external processes designed to remove the unwanted substances which contribute to scale and deposit formations. Regardless of their high efficiency, none of these processes in themselves are capable of removing all substances and a small amount of encrusting solids will be present in the boiler water.

The solids become less soluble in the high temperature of the boiler water and as the water boils off as relatively pure steam, the remaining water becomes thicker with either suspended solids or dissolved solids.

Internal chemical treatment, based on water analysis, is used primarily to precipitate many of the solids and to maintain them as "sludge" in a fluid form. This sludge, along with suspended solids that may be present, must be removed by the blowdown process.

If the concentration of solids is not lowered through blowdown but rather accumulates, foaming and priming will occur along with scale and other harmful deposits.

The scale forming salts tend to concentrate and crystallize on the heating surfaces. Scale has a low heat transfer value. It acts as an insulation barrier and retards the transfer. This not only results in low operating efficiency and consequently higher fuel consumption, but also presents the possibility of overheating the boiler metal. The result can be tube failures or other pressure

I. Routine Operation (3. General, d. blowdown) – Cont'd.

vessel metal damage causing costly repairs and downtime. Deposits of sludge on heating surfaces will have the same detrimental effect.

There are two principal types of blowdown; intermittent and continuous. Intermittent, or sludge, is done manually and is necessary for the operation of the boiler regardless of whether or not continuous blowdown is employed. Continuous blowdown is, as the name implies, a continuous and automatic removal of concentrated water.

1. manual blowdown

The manual blowdown valves and discharge lines are located at the bottom or low point of a boiler so that, in addition to lowering the dissolved solids in the boiler water, a portion of sludge which might accumulate in the lower part of a pressure vessel can also be removed. These valves also provide a means of draining the boiler when it is not under pressure.

When continuous Blowdown is utilized, manual blowdown is primarily used to remove suspended solids or sludge that may have accumulated in the boiler. When continuous blowdown is not utilized, manual blowdown is used to control the concentration of dissolved or suspended solids in addition to the sludge.

In practice, the valves of the bottom Blowdown are opened periodically in accordance with an operating schedule and/or routine chemical control tests. The blowdown amount and schedule should be recommended by a water treating company or a water consultant. It is generally recommended that a steam boiler be blown down at least once in every eight hour period. In cases where the feedwater is exceptionally pure, blowdown may be employed less frequently since less sludge accumulates in the pressure vessel.

From the standpoint of control, economy and results, frequent short blows are preferred to infrequent lengthy blows. This is particularly true when the suspended solids content of the water is high. With the use of frequent short blows, a more uniform concentration of the pressure vessel water is maintained. Blowing down is most effective at a time when the generation of steam is at the lowest rate since the feedwater input then is also low, providing a minimum dilution of the boiler water with low concentration feedwater.

Make sure that blowoff piping and tank, if used, are in proper operating condition, all discharge vents clear of obstruction and that waste is piped to point of safe discharge.

It is recommended that the blowdown valve farthest from the boiler be opened first and closed last, with blowing down being accomplished by the valve closest to the boiler.

The valves should be cracked slightly to allow the discharge line to warm up, after which they can be opened slowly. Quickly close the valve, and if necessary, repeat this now quick opening and closing one or more times.

Close the inboard valve tightly, and then close the outboard valve. Slightly crack open the downstream valve, then close it tightly. The frequency and amount of each blow should be determined by actual water analysis. It is advisable that blowdown does not exceed the necessary amount since it involves heat losses and, if excessive, wastes treatment chemicals.

I. Routine Operation (3. General, d. blowdown) - Cont'd.

The water level should be observed during period of blowdown. If the glass cannot be viewed by the party operating the valve, another operator should watch the glass and direct the valve operator. The blowoff valves should never be left open and the operator should never leave until the blowdown operation is completed and the valves closed. Be sure the valves are shut tight. Repair any leaking valves as soon as possible.

2. continuous blowdown

The boiler is equipped with an internal continuous blowdown pipe and an external stop valve. The collector pipe is located several inches below the low water level at a point where a high level of concentrations is found.

A controlled orifice valve is used in the discharge pipe to allow continual, yet controlled, flow of concentrated water. This removes sediment and oil from the surface of the water, along with the prescribed amount of dissolved solids.

In a boiler that operates continuously at full load, there is little chance for separation of sludge in the lower drum because of the rapid boiler water circulation. Thus, blowdown from the lower part of the unit may not result in the proper elimination of suspended solids. The use, however, of the continuous blowdown does not preclude the regular use of the bottom or intermittent manual blowdown.

The amount of water lost through a continuous surface blowdown is usually considerably less than the water lost through bottom blowoff in order to remove a given amount of suspended solids. The amount of blowdown depends upon the rate of evaporation and the amount of sludge forming material in the feedwater.

Periodic adjustments are made to the valve setting to increase or decrease the amount of blowdown in accordance with a test analysis.

Internal inspection is the only true indication of the effectiveness of water treatment and presence of unwanted solids.

4. Maintenance

a. chemical feed system

Each boiler is supplied with an internal distribution pipe and external shut-off valves. This system may be used to introduce chemical mixtures into the boiler as part of the total control of solids concentration in the boiler water and water treatment. A periodic opening and closing of the shut-off valve is suggested to assure its proper operation and to check valve stem packing tightness.

b. steam gauge

Routinely check the steam gauge for proper operation by closing the gauge root cock, opening drain to blow down the line, close drain, reopen gauge cock and observe repeatability of gauge reading. Temporary removal of the gauge from service for re-calibration using a dead weight tester should be done minimally during scheduled shutdowns.

c. control lines

If pneumatic controls are supplied, routinely blow down the air supply to each control to remove water, oil, dirt, etc. and check all filters.

I. Routine Operation (4. Maintenance) – Cont'd.

d. observation ports

Check and clean port glass. Replace damaged glass with heat resistant pyrex of same type provided.

e. miscellaneous periodic inspection

Frequency of performing the duties will be determined by experience:

1. Check all strainers and filters. Check furnace tubes. Check throat tile for cracks and spalling.
2. Check through observation ports for carbon and slag buildup on burner throat tile and
3. Check for possible seal failure indicated by flue gas leaks, hot spots, or casing discoloration.
4. Inspect valves and piping for leaks that are both inefficient and hazardous.
5. Check casing and structural members for weld failures and cracks.
6. Cleaver-Brooks does not recommend manually popping safety valves. If local regulatory authorities require this to be done, proceed as follows:
   a) Raise steam pressure to near relieving pressure of lowest set pressure.
   b) Grasp handle and pull until steam is released.
   c) Quickly reverse the valve handle and make sure the valve seats stopping all flow.
   d) With steam pressure constant, repeat steps b) and c) on remaining valves.

5. Shutdown

If oil is being fired, operate all sootblowers (if provided) just prior to taking boiler off line.

Reduce burner slowly to low fire position. Blow down boiler and gauge glass. Extinguish flame in accordance with instructions in burner section of this manual.

Close the manual isolation valves at the feedwater flow control valve. Per burner section instructions, close the main fuel train manual shut-off valves and the shut-off valve to the pilot.

For scheduled shut-down after F.D. fan has gone through a post purge of the furnace (if provided) close all system inlet and outlet dampers to assure slow cooling of both pressure parts and refractory. Emergency shutdown may require quick cool down (i.e. F.D. fan and dampers full open) but this is not recommended as normal procedure.

When the boiler has cooled enough to assure no rise in drum pressure, normally after non-return has automatically closed, isolate boiler by shutting main steam stop valve and the non-return valve.

Remove and clean burner oil guns, if applicable, in preparation for next firing. When drum pressure drops to about 15 psig, slowly open steam drum vent valve.

Scheduled or emergency shutdowns should include the purchase of technical service as required and incorporate some or all of the following:

1. Inspection of gas and water sides of pressure parts to detect any evidence of scale/build-up, hot spots, pitting, or corrosion/erosion of all surfaces and take proper action to correct. If chemical cleaning is required, technical assistance should be obtained.

I. Routine Operation (5. Shutdown) – Cont'd.

NOTE!

Prior to entering the boiler, particular care must be taken to guard against steam, hot water, or hot flue gases entering the boiler. Sources will be other equipment still in operation. Careless opening of valves, drains, dampers, etc. connected to the downed unit can cause serious and sometimes fatal results. Boiler must be cooled, vented of all steam pressure and completely drained before removing manhole covers. When individuals are inside the furnace, drums or any other accessible cavity, properly located signs should so note. There should always be at least one person outside the cavity to aid or assist those within. Prior to closing or sealing of any cavity, all personnel must be accounted for and outside the access opening.

2. Inspection of refractories and insulation. Correct any flue gas leaks in casing and its source. Repair or replace consumable burner throat refractories.
3. Check all instruments and controls, re-calibrate if required. Adjustment all of linkages to dampers, jackshafts, valving, etc. (refer to specific service manual).
4. Inspection and testing of safety valves and other safety related equipment per jurisdictional recommendations, and applicable instructions.
5. Inspection, tightening, or replacement of all gasketed surfaces.
6. Inspection, cleaning, replacement or re-gasketing of all liquid level gauges, indicators, and transmitters. Make sure all means of boiler water level indication and piping are in good working order.
7. Inspect all drains, vents, blow-off, bypasses, isolation, and other valving for proper operation.
8. Review of recorded data for any required adjustments (i.e. fuel/air ratios, fuel pressure or temperature, instruments and controls, etc.)
9. Lubrication and oiling of all normally lubricated equipment. Inspection of moving parts for wear, misalignment, and replacement.
10. Inspect installed soot blowing equipment for wear, misalignment, and proper operation. Cleaned surfaces, where possible, should be checked for cleanliness, build-up, and wear from cleaning medium impingement.
11. Check associated equipment for proper operation such as fans, pumps, burner, controls, deaerators, economizers, superheaters, dampers, air heaters, heat exchangers, non-return and stop valves, etc. (Refer to specific service manuals).
12. Have in stock all items or components that will be replaced.

a. annual (or longer) scheduled shutdown

Boilers must be removed from service periodically in order to perform a thorough inspection. Timely notice from the proper authority, the insurer, local or state legal jurisdiction is given and the authorized boiler inspector usually oversees the entire procedure which should be recorded in a log as a history and to establish good future procedure.

Prior to taking the boiler out of service, it is not necessary to pop the safety valves. Check the valve, drip pan elbow, discharge pipe, and drains for proper installation.

While a scheduled inspection pertains primarily to the fireside and waterside of the pressure parts, a review of the daily operating log provides the operator the opportunity to check and correct all other boiler appurtenances as well as other ancillary equipment.

Replacement spare parts, if not on hand, should be ordered sufficiently prior to shutdown.

I. Routine Operation (5. Shutdown, a. annual or longer) – Cont'd.

When shutting down, the load should be reduced gradually and the pressure vessel cooled at a rate that avoids damaging temperature differential that can cause harmful stresses. Vessels should not normally be drained until all pressure is relieved and water temperature is less than 120°F, again to prevent uneven contraction and temperature differentials that can cause expanded tubes to leak. Draining the unit too quickly may cause the baking of deposits that may be present on the heating surfaces. Some heat, however, may be desirable to dry out the interior of the boiler.

If the internal inspection is being made at the request of an authorized inspector, have the inspector indicate whether he desires to observe the conditions prior to cleaning or flushing of waterside surfaces and performing fireside repairs.

Be certain that a supply of manhole gaskets is available along with any other gaskets or items needed to place the unit back into operation after inspection.

Have available information on the boiler design, dimensions, generating capacity, operating pressure or temperature, time in service, defects found previously and any repairs or modifications. Also have available for reference records of previous inspections.

Be prepared to perform any testing required by the inspector including hydrostatic.

CAUTION!

Boiler must be cooled, drained, and at atmospheric pressure before opening drums

After proper cooling and draining of vessel, flush out the waterside with a high pressure water hose. Remove any scale or deposits from the waterside surfaces and check for internal or external corrosion and leakage.

CAUTION!

Boiler setting must be cooled to ambient temperature before entering furnace.

The fireside surfaces should also be thoroughly cleaned so that metal surfaces, welds, joints, tube ends, fittings and any previous repairs can be readily checked.

If convection bank gas baffles are supplied, check them for excessive erosion which may cause high stack temperatures and reduced efficiency.

Be sure that steam valves, system valves, (hot water) feedwater valves, blow-off valves, all fuel valves, valves to expansion tanks, drain and vent valves, and electrical switches are shut off prior to opening the drums or the combustion area. Adequately ventilate the pressure vessel and furnace prior to entry.

Cleaners should preferably work in pairs. Always have one man standing by outside when a man is working inside a boiler.

Clean out the low water cut-off piping, the water level controls and cross connecting piping. Replace water gauge glass and clean out water gauge valves and trycocks. Also check and clean drain and blowdown valves and piping.

Check all water and steam piping and valves for leaks, wear, corrosion and other damage. Replace or repair as required.

I. Routine Operation (5. Shutdown, a. annual or longer) – Cont'd

If any deposits are noted during these inspections, they should be flushed out with a high pressure hose. If they are not thoroughly removed by flushing, this may require immediate consultation with your water treatment representative. In a few cases, it may be necessary to resort to acid cleaning. Professional advice is definitely recommended should acid cleaning be required.

The effectiveness of treatment, water conditions and the amount of fresh water makeup required are all factors to be considered in establishing frequency of future pressure vessel inspections. The service of a water treatment company should include periodic pressure vessel inspection and routine water analysis.

b. pressure vessel care and repair

1. fireside inspection

Wire brush or sweep away any deposits that might be present in the furnace area. If excessive soot or any signs of corrosion are evident, prompt corrective action must be taken. Combustion adjustments should be made to prevent further occurrences. Poor combustion contributes to a dirty boiler, adds hazards and raises operating costs.

Check the condition of all the refractory. Particularly check the expansion joints in the front and rear walls, the seals at the corners and the throat tile. Patch and repair as required.

One form of external corrosion to the pressure parts can occur when fuel containing sulphur is burned under low or cycling load conditions. Moisture in the flue gas will condense at low temperatures and form sulfuric acid. It can also occur when boilers fouled with soot sit idle. This condition can be minimized by proper operation of the sootblowers and constant checks on the combustion process.

The burning of fuels with high vanadium, sodium, nickel, ash and/or iron content can cause extremely dense and tenacious deposits which are impossible to remove by sootblowing. These fuels should be avoided or proper additives used to control fouling by elevating the melting point of the deposits, or by making the deposits easily removable by sootblowing. When these deposits occur, every effort should be made to manually remove them from the tubes.

The breeching and stack should be inspected periodically and cleaned if necessary. Also inspect the stack for any signs of damage or wear.

The fireside should be thoroughly cleaned prior to any extended lay-up of the boiler. Depending upon circumstances, a protective coating may be required. See the section on storage.

I. Routine Operation (5. Shutdown, b. pressure vessel care) -Cont'd.

2. waterside inspection

A well maintained and operated boiler with properly treated water will require a minimum of repairs. Periodic inspection of the pressure vessel will reveal its condition, oftentimes permitting corrective action designed to prevent failure of some portion of the boiler. Observe all safety precautions before entering the boiler for inspection or repairs. This includes securing the burner and positive action in ensuring all valves in lines to and from the boiler are closed and remain closed.

Corrosion and erosion, or a combination of both, are a chief cause of tube failure. Corrosion is a chemical action occurring inside or outside the tube wall. Internal corrosion appears as pitting or a general failing of the tube wall. Pitting occurs when there is free oxygen in the water whereas general thinning indicates an acid condition in the boiler water. External corrosion is very likely to occur when a full boiler covered with soot lies idle. Most soot contains some percentage of sulfur which in the presence of moisture from condensation forms a highly corrosive acid.

Erosion takes place when considerable quantities of fine particles are driven at high velocity against the outside surfaces of the tubes. Erosion may also be caused by sootblowers if nozzles are not kept in proper alignment.

Over-heating also contributes to damage. This usually occurs when a tube is heated to a temperature which reduces its tensile strength. The weaker walls then rupture under normal operating pressure. The chief cause of over-heating is scale on the water side of the tubes. Scale is a poor conductor of heat and the cooling ability of the boiler water is lessened. Low water is another cause of over-heating since circulation of water is impaired and the tube is starved of water. An oily film also acts as an insulator permitting over-heating. Any sign of oil in the boiler should be considered serious and prompt action taken to remove it.

Over-firing a boiler, to produce more steam than intended by its design, will also shorten the boiler life, with the tubes being first to suffer.

If small leaks occur, locate their source and repair them as quickly as possible. A build-up on the fireside of solidified water treatment chemicals is indicative of a leak. Leaking manholes and handholes should be corrected promptly. Gasket sealing surfaces should be cleaned thoroughly to provide a tight seal.

Minor or leaking repairs may be handled by authorized and experienced personnel. Any repairs beyond this must have the approval of an authorized inspector. His recommendations and advice must be followed. If welding is required, the welder must be certified to do the work.

Boiler tubes are secured in the boiler drums by rolling or expanding to a tight fit. In the correction of any leak, it is imperative that re-rolling of the leaking tube be done only by experienced personnel. Inexperienced operators tend to over roll the tube, thus thinning the joint and making it difficult to tighten under any circumstances. When seal welding is employed, a light re-rolling should be made after welding

3. tube care

In addition to the care of tubes discussed above, there is a method of cleaning tubes referred to as turbining or punching which is accomplished through the use of motor driven rotary cutting tools and brushes. The necessity for and frequency of this type of cleaning is determined by an internal

I. Routine Operation (5. Shutdown, b. pressure vessel care-tube care) – Cont'd.

inspection. The type of deposits will determine the need for using cutting or scraping tools and a brush or a brush only. Air driven tools are most commonly used, although other power driven tools may be employed. Cleaning tools furnished by or obtained from Cleaver-Brooks are selected for the size of the boiler tubes and for their ability to negotiate the bends of the tubes.

The mechanical cleaning of tubes and the use of these tools should be done by experienced operators or at least under their supervision. There are companies who specialize in cleaning and their experience and equipment will quite often justify their employment.

This work is generally done from within the upper drum, working the tool down through the tubes so that debris falls into the lower drum where it can be collected and removed. The baffle plates in the upper drum will have to be removed for access to the tubes.

There are several general operating suggestions that should be followed as good operating practices.

a) Start the cleaner rotating in the tube and pass it slowly and uniformly through at approximately two to three feet per minute.
b) Do not allow cleaner to protrude from the tube while under power. This can be dangerous to personnel and damaging to equipment.
c) Care should be taken not to allow the cleaner to stop in any one position in the tube.
d) Keep working tools in good condition.
e) If electrical driven tools are used, be sure they are properly grounded.

Specific operating instructions are provided by the manufacturer of the tube cleaning equipment.

4. chemical cleaning

Should a waterside inspection reveal a deposit build-up that cannot be fully removed by flushing or mechanical means, it may be necessary to clean with chemicals (acid). Professional advice is recommended. There are specialist companies equipped to provide complete chemical cleaning service. Your feedwater consultant should be contacted and be aware of the situation.

5. water column

Refer to specific manufacturer service instructions for the repair or replacing of components such as probes or float mechanisms. Probes must not be over torqued and should be handled carefully to prevent breaking of porcelain insulators. Float mechanisms must be routinely cleaned and checked for wear to assure unrestricted travel as required.

Gauge glasses must be routinely cleaned or replaced. Tubular glasses must be correctly aligned in their respective steam and water shut-off valves to prevent breakage. The glass must be sealed with a correct rubber O-ring type packing where inserted in the valve and tightened only sufficiently to seal. Over tightening will break the glass. Prismatic and reflex type gauge glasses require servicing per specific manufacturer's instructions, as do gauge valves and trycocks.

When putting gauge glasses back into service, slowly bring them up to operating temperature by opening the drain valve and with the water gauge valve closed, just crack the steam gauge valve. After 5 – 10 minutes, close the drain valve and open both gauge valves. Check for clear steam/water passage as previously described.

I. Routine Operation (5. Shutdown, b. pressure vessel care) – Cont'd.

6. safety valves

Inspection and testing should be in accordance with the instructions of the boiler inspector or other jurisdiction. Valve repair is to be done only by the manufacturer or his authorized representative

7. care of refractory

The following areas should be checked at every opportunity and necessary repairs made:

a) Where tubes or their extensions (fins or metal seals) meet refractory walls, fill all voids with Kaowool or equivalent ceramic fiber.
b) Check all refractory wall surfaces. Cracks 3/8" wide or less are not considered excessive and will close when the boiler is hot. Fill wider cracks with ceramic fiber.
c) Check plastic refractory seals normally located at upper and lower drums to prevent flue gas bypass for tightness, cracks, and voids. If gaps appear between plastic and tubes or drums, fill with high temperature refractory cement.
d) If arch or full circle tile surround the burner refractory throat tile, any cracks between the two should be packed with ceramic fiber.
e) Cracks appearing in the burner throat tile should be filled with high temperature refractory cement.
f) High temperature castable cracks or voids at tubes, seals, or casing junctures should be filled with high temperature refractory cement or where thermal growth is expected packed with ceramic fiber.

NOTE!
Some residual fuel oils contain impurities such as vanadium, sodium, sulphur, and alkalis in concentrations that can cause fluxing, spalling, and premature cracking in the refractory. These conditions can be avoided completely only by changing to cleaner fuels. Limited control of these more destructive fuels can be achieved by using various fuel additives, adjusting firing conditions, and constant monitoring and care of the refractory.

c. care of idle boilers

When a boiler is taken out of service, the boiler should be cooled until the water is below the atmospheric boiling point. The boiler should then be emptied and flushed out with a high pressure water hose. An inspection should be made to determine what repair work is necessary and what mechanical and/or chemical cleaning should be done. A decision should then be made on whether to employ dry storage or wet storage. Since freshly cleaned metal surfaces are much more vulnerable to storage corrosion than surfaces that have operational oxides on them it is preferable to delay chemical cleaning until the boiler is ready to be returned to service.

1. dry storage

This procedure may be preferable for boilers out of service for extended periods of time or in locations where freezing temperatures may be expected.

The boiler should be thoroughly dried, since any moisture left on the metal surface would cause corrosion to occur over long idle periods. After drying, precautions should be taken to preclude entry of moisture in any form from steam lines, feed lines, or air.

I. Routine Operation (5. Shutdown, c. care of idle boilers-dry storage) – Cont'd.

For this purpose, moisture-absorbing material, such as quicklime at the rate of 2 lb. (0.9 kg) or silica gel at the rate of 5 lb.(2.25 kg) for 30 cu. Ft. (0.86m3) of boiler volume, may be placed on trays inside the drums to absorb moisture from the air. The manholes should then be closed and all connections on the boiler should be tightly blanked. The effectiveness of the materials for such purposes and need for their renewal may be determined through regular internal boiler inspections.

2. wet storage

A wet procedure may be used for a boiler to be placed in stand-by condition. Wet storage is particularly useful if the standby boiler may be required for service at short notice or if it is impractical to employ a dry storage procedure. The method is not generally employed for boilers which may be subjected to freezing temperatures unless a source for heating the water is available. Several alternative procedures have been employed:

The empty boiler should be closed and filled to the top with water and conditioned chemically to minimize corrosion during standby. Water pressure greater than atmospheric should be maintained within the boiler during the storage period. Consult the chemical treatment company for the proper chemical procedure to be followed.

As an alternative, the boiler may be stored with water at normal operating level in the drum and nitrogen maintained greater than atmospheric pressure in all vapor spaces. To prevent in-leakage of air, it is necessary to supply nitrogen at the vents before the boiler pressure falls to zero as the boiler is coming off the line. If boiler pressure falls to zero, the boiler should be fired to re-establish pressure and superheaters thoroughly vented to remove air before nitrogen is admitted. All partly filled steam drums and superheater headers should be connected in parallel to the nitrogen supply. If nitrogen is supplied only to the steam drum, nitrogen pressure should be greater than the hydrostatic head of the longest vertical column of condensate that could be produced in the superheater.

3. fireside storage

When boilers are removed from the line for an extended period of time, fireside areas must also be protected against corrosion.

The fireside areas will contain deposits, particularly from the convection section through the economizer and air heater section that are hydroscopic in nature. When metal surface temperatures drop below the dew point, condensation will occur, and if acidic hydroscopic deposits are present, corrosion can result.

If the firesides are to be left open, the metal surfaces must be maintained above the dew point by circulation of warm air. Depending on the location of the boiler, this can be done by circulating the boiler room air through the fireside area or by circulating air blown over a heater with fans. As a minimum, the fireside areas can be maintained above ambient dew point conditions by circulating warm air. For maximum protection, the fireside areas should be cleaned prior to storage. If the boiler is to be completely closed up, silica gel or lime can be used to absorb any water of condensation. An alternate would be to spray or wipe the metal surfaces with a light oil such as Consul oil.

I. Routine Operation (5. Shutdown, c. care of idle boilers-fireside storage) – Cont'd.

When dry storage procedure involving moisture absorbing material is applied to the internal pressure parts and/or the furnace area, care must be taken to remove all this material before filling the boiler or lighting the burner. Warning signs conspicuously posted should read as follows:

WARNING!
Moisture absorbing material has been placed in the waterside and furnace of this boiler. This material must be removed before boiler is filled with water or burner is fired. Inspect periodically and replace with new or regenerated material.

III. SPECIAL APPLICATION EQUIPMENT

A. Superheater

1. General

Correct operational procedures must be followed during boilout, startup, operation, and shutdown of a superheater equipped boiler to prevent damage to the superheater. It is essential that all operators be properly instructed and understand the specific procedures applicable to superheater operation.

The convection type superheater consists of inverted loop tubes called "elements" connected to upper and lower headers positioned horizontally. Steam supply from the steam drum through the crossover header or manifold enters the upper (inlet) header. The superheater steam outlet is located below the inlet header. The superheater is fully drainable.

The superheater design is such that all steam generated by the boiler must pass through the superheater and positive flow of steam MUST be maintained at a quantity sufficient to absorb the heat at any given firing rate.

WARNING!
Serious damage to the superheater may occur if correct operating procedures are not rigidly followed.

Any imbalance in the rate of steam flow through the superheater and the rate of the heat input may result in elevated metal temperatures that could cause superheater tubes to overheat and subsequently fail. Such damage can occur not only during normal operation, but also during startup and shutdown periods.

WARNING!
Virtually all SUPERHEATER FAILURES are due to boiler or plant operators inadvertently or unknowingly using the wrong procedure to start up and/or shut down superheated boilers.

2. Boilout

The superheater provided for this boiler is a completely welded unit and will have little grease or oily matter on the internal surfaces. Boilout is not required to clean the superheater surfaces. Depending on the application, Cleaver-Brooks recommends a sufficient steam blow to assure the internal surfaces are clean, before normal operations.

WARNING!
To establish steam flow through the superheater elements during startup and shutdown periods, a SUPERHEATER START-UP VENT VALVE is supplied on all Nebraska Boiler superheaters. The vent valve is positioned in the superheater outlet piping or header up-stream of the non-return and stop valves. Refer to the general arrangement drawing for vent valve location. Refer to Superheater Startup Procedures for vent valve use.

During installation, the discharge side of the vent valve should be piped to atmosphere and a safe location, if possible steam exhaust visible to operating personnel. Normal piping practices should be followed, using short straight runs to minimize back pressure. The pipe size should never be less than the valve size. Piping that could result in trapped condensate is not allowed.

A. (Superheater, 2. Boilout) – Cont'd.

WARNING!
STEAM SHOULD NEVER BE EXTRACTED FROM ANY SOURCE BETWEEN THE STEAM DRUM AND THE SUPERHEATER OUTLET HEADER UNLESS AUTHORIZED IN WRITING BY CLEAVER-BROOKS.

3. Start-up Procedure

a) Prior to boiler startup, open each of the following valves:
   1. All superheater header drain valves.
   2. The superheater outlet drain valve.
   3. The superheater start-up vent valve.

b) Refer to the General Arrangement drawings for location of all valves. The start-up vent valve will remain open throughout boiler startup to ensure cooling of the SH tubes.

c) Boiler feedwater must be available at the proper pressure and temperature.

d) Boiler water level must be at normal operating level prior to light-off.

e) Start burner at minimum firing rate. If the boiler is cold, intermittent firing of the burner is recommended. A firing schedule of 5 minutes on and 20 minutes off may be used for the first hour. Time should be extended 1 to 2 hours when ambient temperature is below 80°F.

WARNING!
AT NO TIME SHOULD THE BOILER FLUE GAS OUTLET TEMPERATURE BE ALLOWED TO INCREASE MORE THAN 100°F PER HOUR DURING STARTUP.

As intermittent firing continues, steam pressure will begin to rise. Firing frequency may be increased from low fire position as long as boiler gas outlet temperature does not increase at a rate exceeding 100°F per hour.

As pressure continues to rise, it is necessary to monitor superheater outlet steam temperature. Steam temperature should increase gradually and at 100% MCR should be at design outlet temperature. If the superheated steam temperature reaches design temperature before unit is at 100% MCR, the **FIRING RATE IS EXCESSIVE AND SHOULD BE REDUCED OR SHUT DOWN IMMEDIATELY.**

CAUTION!
DO NOT DEPEND ON PANEL INSTRUMENTATION (unless calibrated) DURING INITIAL OPERATION OF THE UNIT. INSTRUMENT STEAM TEMPERATURE SHOULD BE COMPARED WITH A CALIBRATED THERMOMETER AT THE SUPERHEATER OUTLET.

Monitor superheater drains. Water will be replaced by wet steam. The valve may be throttled but not closed until dry steam is evidenced from each specific drain exhaust. This usually occurs when the superheater outlet pressure is 10-20 psig.

Superheater outlet temperature should be monitored closely to ensure that it does not exceed the maximum permitted temperatures.

Continue building drum pressure, venting all steam through the superheater vent valve. Continually monitor superheater steam temperature.

SPECIAL APPLICATION EQUIPMENT

A. Superheater (3. Start-up Procedure) – Cont'd.

When superheater outlet pressure reaches plant operating pressure, the non-return **(S14)** may be opened and the stop valve opened slightly to establish low steam flow to the main header. Care should be taken to slowly heat up the main header to prevent any steam/water slugs that can cause severe damage. When the header is hot, the stop valve can be fully opened.

NOTE: To establish minimum desired steam flow, the firing rate may have to be increased gradually in 5-10% increments.

WARNING!
ONLY WHEN STEAM FLOW IS ESTABLISHED TO THE MAIN STEAM HEADER CAN THE SUPERHEATER VENT VALVE BE FULLY CLOSED.

The boiler is now on line. The firing rate may be carefully increased to accommodate plant demand and conditions.
The above procedures should take a minimum of four (4) hours to complete. This procedure is recommended when bringing the unit on line from a cold start. Normal boiler operating procedures are to be followed after a superheater unit is put on line. It is recommended that operation be discontinued when steam flow is reduced below 10% of MCR. As in all boiler operations, it is essential to maintain proper water conditions and combustion parameters in accordance with original design and operating criteria.

The following table is offered as a guide to illustrate the recommended times required to place a superheater equipped boiler on line. Sufficient startup time is mandatory to adequately protect the superheater from unacceptable abuse.

TIME HOURS	STEAM PRESSURE, PSIG
1	1
2	30
3	90
4	225
5	440
6	750

4. Shutdown Procedure

Special precautions are to be followed when shutdown of a superheated boiler is performed. As in startup, so also in shutdown sufficient steam flow through the super-heater must be maintained at all times to avoid overheating, oxidizing, or "burning" of the elements.

With boiler controls in manual mode, reduce the firing rate to minimum fire.

Shut down the burner. Under normal cool-down, the forced draft fan would be off at this time after going through a post-purge of the furnace, if applicable.

Superheater temperature will decrease as the furnace cools. The superheater outlet pressure will drop until the non-return valve closes, preventing any back flow of steam. The super-heater vent may be throttled closed proportionally to superheater temperature. With 5-10 psig on the superheater outlet header, open the superheater drain valves to remove any condensate.

A. Superheater (4. Shutdown Procedure) – Cont'd.

WARNING!
UPON EMERGENCY SHUTDOWN OR BURNER TRIP, THE SUPERHEATER VENT VALVE MUST BE OPENED IMMEDIATELY. AT NO TIME SHOULD THE BURNER MANAGEMENT SYSTEM BE ALLOWED TO RECYCLE. EACH SUPERHEATER STARTUP IS UNDER MANUAL OPERATION. PRESSURE DECLINE IN THE DRUM SHOULD BE CONTROLLED FOR A GRADUAL COOL-DOWN.

B. Economizer

1. General

The economizer is designed to indirectly heat deaerated, chemically treated boiler feedwater with hot flue gases. The following paragraphs describe the intended operation of this equipment.

2. Pre-installation

This product is not protected to withstand extended out-of-doors storage. The unit should be protected from the rain. Although rust is not harmful to the operation of the unit, it could cause damage to control valves installed downstream. The unit has not been freeze protected. This unit was drained at the factory.

Do not move or set the unit in such a manner as to have the tubes hang in the vertical position as serious damage to the finned tube bundles may occur.

Prior to installation, remove all shipping covers and check gas passages for miscellaneous debris. Assure that gas side full flow area is available.

3. Installation

Set unit in place on supporting structure capable of carrying the operating weight of the unit. Care should be taken to ensure the tubes are horizontal and level to avoid the possibility of steam pocketing and to ensure drainability.

Weld or bolt economizer gas side connections to the gas inlet and outlet duct work. The inlet duct work should be as short as possible, gas tight and well insulated. The inlet transition should be designed to allow an even distribution of flue gas across the entire gas inlet.

The economizer is not equipped with a safety relief valve, since the economizer is not isolatable from the boiler.

The feedwater flow control valve is located up-stream of the economizer.

It is also important that the header vent and drain connections be valved and readily accessible to the operator. Even though the unit may be installed inside the boiler room, it is quite often overlooked that when the boiler is shut down, cold air can be drawn down through the stack and into the boiler room. This could allow the economizer to freeze even though the flow of air is small.

A thermometer should be installed on the water inlet and water outlet piping in a position to be easily accessible and visible. A water pressure gauge should be installed at the water inlet header.

After the unit is installed, the water passages should be thoroughly flushed and drained.

SPECIAL APPLICATION EQUIPMENT

B. Economizer (3. Installation) – Cont'd.

4. Operation

For initial start-up, open vent valve, fill the economizer with water being careful to force any trapped air through vent valve.

Close vent valve and proceed with standard boiler start-up procedure.

Start-up of the economizer while boiler is on line ("Hot Start") is not recommended. Contact factory for special instructions if "Hot Start" cannot be avoided.

Any operation of the unit with cold, untreated or undeaerated water can severely damage the unit and result in voiding warranty.

Maintaining the recommended inlet feedwater temperatures will serve to avoid corrosion on both the gas and water sides of the heating surfaces:

a) Heating the water to specified temperature will protect the unit against cold end corrosion when burning sulfur laden fuels.
b) Heating the water to or close to the boiling point before pumping to the boiler will deaerate the water by driving out the oxygen entrained in cool water. Thorough deaeration and water treatment (softening) will avoid corrosion and scaling of internal tube surfaces in the unit.

Should a tube leak develop, bypass the water and allow the unit to boil dry. Make repairs at the next shutdown.

Field repairs can be made by the owner. If replacement parts are required, ASME Code certified material should be used and a code qualified welder and procedure should also be utilized. An authorized National Board Pressure Vessel Inspector should witness any repairs.

It is preferable that the sootblower be used as seldom as possible, and then only with boiler on load – preferably at or near full load. The steam line to the sootblower should be well drained before opening the operating valves.

5. Operation with Corrosive Fuels

When reviewing the inclusion of an economizer in the overall heat transfer of a system, two important conditions must be considered which are:

a) Sulphur content of the fuels utilized.
b) Feedwater inlet temperature to the economizer.

Any fuels that contain sulphur will combine with oxygen during combustion and the products will be SO2 and SO3. When these products combine further with moisture (i.e. H2O in fuel or combustion air) to form sulphurous and sulphuric acids, tube attack and failure result. To minimize or eliminate this attack, feedwater inlet temperature should be maintained above 240°F.

If minimum inlet feedwater temperature is unattainable during certain portions of operation that could result in problems, contact Cleaver-Brooks for discussion of options, such as tube in shell feedwater heaters, etc.

WARNING!
It is the temperature of the tube metal surface, not the flue gas exit temperature that determines potential corrosive attack of the tubes.

IV. MISCELLANEOUS

A. Flue Gas Recirculation

When specified to meet certain environmental requirements, overall system performance requires addressing NOx emissions in the products of combustion. Individual burner manufacturers have different approaches to meet required NOx emissions.

For this project, recirculated flue gas into the combustion process is used for reduction of NOx. Duct work connects the flue gas exiting the system) to the forced draft fan inlet. This duct is sized to allow 15-30% of the flue gas to be recirculated. The pressure at the duct inlet is 0 to positive pressure, pressure at the fan inlet is negative and natural induced draft results. A damper for FGR flow control is provided.

B. Cold Water Start

1. Hydrostatic Test

If water is less than 100°F entering the boiler at any time, care must be taken to raise the water temperature to 100-120°F very slowly.

WARNING!
As cold water is never desirable, every effort should be made to heat boiler water, including the temporary use of steam or electric heating coils in the water supply.

Failure to raise the water temperature (and metal temperature of the fire side) very slowly may result in thermal shock and stresses leading to tube leaks and possibly cracked tubes. If the main burner is used to heat cold water, it should be on only 20 minutes per hour at low fire. A safer and more steady approach to heating the pressure parts and water would be to use the pilot ignitor only. Check with the supplier of the pilot to determine the pilot's gross BTU input and suggested gas supply pressure to obtain 2,000,000 BTU/HR input.

The following example calculates the time required to heat 70,000 lbs (water) from 60°F to 120°F assuming 50% heat absorption:

HRS = #Water (Enthalpy [120°-60°] ÷ Absorption Rate
= 70,000# (87.92-28.06) BTU/# ÷ 1X10 6 BTU/Hr
= 4.19 Hrs.

Therefore, in approximately 4 hours the boiler pressure parts are warm enough to proceed with the hydrostatic test. Be sure the steam drum vent is left open when boiler is fired to release any steam. The boiler should be filled to water flow from the vent, vent shut, and pilot off prior to proceeding with hydro.

2. Boiler Boilout

If water available for boilout is less than 120°F, the above pilot warm-up procedure should be used until water temperature reaches 120°F. At this point, operate the main burner to proceed with boilout, starting and stopping the burner as required so that exit flue gas temperature rise does not exceed 100°F/Hour. At this point refer to standard boilout procedure at II, C, 4. in this manual.

MISCELLANEOUS

B. Cold Water Start – Cont'd.

3. Initial Startup

If water less than 120°F is used at startup, heating the boiler should follow the above pilot warm-up at every cold water start. After water temperature reaches 120°F, operate main burner at low fire, starting and stopping the burner as required so that flue gas exit temperature rise does not exceed 100°F/Hr. If feedwater remains less than 200°F once boiler is up to pressure and on line, do not fire the burner at more than 10% MCR. Steam at this 10% MCR should be sent out into the system as soon as possible in an attempt to get condensate return used to heat the feedwater.

NOTE!

Firing a boiler above 10% MCR with feedwater temperature below 200°F is not recommended. The numerous starts and stops the boiler is subjected to during overall system "Shakedown" can result in conditions that may negate warranty. Contact Cleaver-Brooks before proceeding.

C. Manway Plate Joint Sealant Installation

1. Remove the old gasket and clean both the manway plate and the manway ring. The surfaces should be free of scale and particulate matter, but need not be as smooth as for other gasketing materials.

2. The joint sealant supplied is ½" wide which is recommended by the manufacturer for a 12" x 16" manway.

3. Remove the paper from the factory applied adhesive strip and apply the joint sealant to the inside face of the manway ring as shown below.

4. Install the manway plate, bolts and crabs in place with a snug fit. Adjust plate so the edge of the joint sealant can be seen all around the inside of joint. Then pull down nuts but not excessively. Joint sealant does not require compression to seal.

Overlap Ends As Shown
Joint Sealant Viewed From Inside Drum
Joint Sealant Install. Flush with Inside of Manway Ring

"There are no oral, express, or implied (including but not limited to warranties of fitness for a particular purpose or merchantability) warranties being provided by seller to buyer with respect to any manway plate joint sealant ("Goods") sold or instruction provided herein. The seller shall not be liable for any special, indirect, incidental, punitive, or consequential cost or damages arising from the use or installation of goods or from any other cause whether based upon warranty, tort, contract or otherwise, regardless of any devices or recommendations that may have been rendered concerning the purchase, installation, or use of Goods."

WARNING!
IMPROPER INSTALLATION OF JOINT SEALANT COULD CAUSE BODILY INJURY AND/OR PROPERTY DAMAGE

D. Discussion of "Free-Blow" Valves

There are certain drain and vent valves and their piping that should incorporate "Free Blow" valving, especially during startup and shutdown of the boiler.

D. Discussion of "Free-Blow" Valves – Cont'd.

"Free Blow" is defined as: to the atmosphere so that the person controlling the particular valve can visually observe the flow of steam, condensate, or water. The valve may be without any down stream pipe, with a short run of pipe to an atmospheric drain, or piped to an atmospheric funnel that acts as a collection manifold for a number of valves.

Valves that should incorporate "Free Blow" arrangements are:

1. Water Column Gauge Glass Drain
2. Sootblower Steam Line Drain
3. Superheater Drains
4. Superheater Vent
5. Economizer Vent
6. Steam Drum Vent
7. Superheater Crossover Header Vent
8. Vents at all High Points of Piping or Equipment that can allow trapped air pockets to persist.

Visual observation of flow from these valves is needed to assure proper startup, operation, and shutdown of the boiler system.

E. Steam Purity

Cleaver-Brooks standard labyrinth steam separators are provided to ensure dry steam to the superheater tubes.

V. PARTS ORDERING

A. General

Due to the specifics and magnitude of each boiler system, the Aftermarket Department creates job specific spare parts lists. The finalized list is available at time of shipment and/or startup of the unit

In order to expedite delivery of spare or warranted parts, the following historical data, when available, is required.

1. Boiler or unit serial number found on the boiler mounted nameplate.
2. Complete "Sold To" address.
3. Complete "Ship To" address.
4. Date unit was shipped.
5. Date unit was started.

When ordering parts, furnishing complete information is mandatory, and in addition to the above data includes:

6. Cleaver Brooks Boiler part number (refer to parts list, drawing number, or vendor data).
7. Quantity of each part.
8. Method of shipment
9. Shipping address (if different than "#3") and specific instructions.
10. Date parts are required.
11. Your purchase order number.

If spare parts are required from vendor supplied equipment (i.e. motor, pump, transmitter, instrument, etc.), be sure to include all available data found on the specific equipment nameplate such as model number, serial number, etc.

Parts may be returned for repair but, prior to shipping, contact the Aftermarket Department for shipping instructions which may involve direct shipment to a vendor. Prior to packaging, remove fittings and other accessories, properly drain and clean the part, and pack to eliminate shipping damage. Include in the package your purchase order or letter authorizing repair and a packing list identifying all parts shipped.

If a part is presumed "Defective in Warranty" prior to shipment, contact our Aftermarket Department for shipping instructions.

Routine orders should be sent to the nearest Cleaver Brooks Representative when available.

Parts Orders can also be sent to
Cleaver Brooks Aftermarket Department
Phone 414-359-0600
Fax 800-688-9010
Or email to IWTPARTS@CLEAVER-BROOKS.COM

LAYING UP OF BOILERS

Water Side

When a boiler is taken out of service, the boiler should be cooled down to 10 psig and drained. An inspection should be made to determine what repair work is necessary and what mechanical and chemical cleaning should be done. A decision should then be made on whether to employ dry storage or wet storage. Wet storage is preferred if freezing can be prevented. Since freshly cleaned metal surfaces are much more vulnerable to storage corrosion than surfaces that have operational oxides on them, it is much preferred to delay chemical cleaning until the boiler is ready to be returned to service.

A dry storage procedure may be preferable for boilers out of service in locations where freezing temperatures may be expected during standby.

The boiler should be thoroughly dried since any moisture left on the metal surface would cause corrosion to occur on long standing. After drying, precautions should be taken to preclude entry on moisture in any form from steam lines, feed lines, or air. For this purpose, moisture absorbing material, such as quicklime at the rate of 7 lb or silica gel at the rate of 8 lb for 100 cu ft of boiler volume, may be placed on trays inside the drums to absorb moisture from the air. The manholes should then be closed and all connections on the boiler should be tightly blanked. The effectiveness of the materials for such purposes and need for their renewal may be determined through regular internal boiler inspections.

Alternatively, air dried externally to the boiler may be circulated through it. The distribution should be carefully checked to ensure that the air flows over all areas.

It is usually acceptable in the case of large industrial or utility boilers to simply drain the boiler while feeding nitrogen to the boiler vents and to maintain a 5 psig nitrogen pressure during storage period.

A wet storage procedure may be used for a boiler to be placed in standby condition. Wet storage is particularly useful if the standby boiler may be required for service at short notice. This method is not generally employed for reheaters of for boilers which may be subjected to freezing temperatures.

The empty boiler should be closed and filled to the top with water that has been conditioned chemically to minimize corrosion during standby. Water pressure greater than atmospheric should be maintained within the boiler during the storage period. A head tank may be connected to the highest vent of the boiler to maintain pressure above that of the atmosphere, or 5 psig nitrogen overpressure may be used.

For a short storage period on boilers below 1000 psig, condensate or feedwater containing approximately 200 ppm of sodium sulfite may be used for filling the boiler, adjusting the pH to 10 with any convenient alkali. If the superheater is of the drainable type it can also be filled with the same treated water by overflowing from the boiler. Superheater tubes must be completely drained and flushed with condensate before restarting the boiler.

If the superheater is nondrainable, it should be filled only with condensate or demineralized water containing a minimum of dissolved solids, not more than 1 ppm. Before introducing the water into the superheater, mix in uniformly about 200 ppm of hydrazine and sufficient volatile alkali, such ad ammonia, cyclohexylamine, or morpholine, to produce a pH of 10. The treated water may be introduced into the superheater through an outlet header drain or the attemperator spray water line until the water overflows into the boiler. When the superheater is filled, close the drains and vents.

The boiler can now be filled through the feedwater or other filling line with condensate or with feedwater treated with hydrazine and additional volatile alkali. If the storage period is expected to exceed 3 months, the concentration of hydrazine should be doubled.

If preferred, on boilers below 100 psig, the boiler may be filled using feedwater or condensate treated with sodium sulfite or hydrazine as described above after the superheater is first filled with condensate treated with hydrazine and additional volatile alkali. On boilers above 1000 psig, hydrazine and volatile alkali must be used to prevent any solid deposition in the boiler after storage.

As an alternative, the boiler may be stored with treated boiler water at normal operating level in the drum and nitrogen maintained at 5 psig pressure in all vapor spaces. To prevent in-leakage of air, it is necessary to supply nitrogen at the vents before the boiler pressure falls to zero as the boiler is coming off the line. If boiler pressure falls to zero, the boiler should be fired to reestablish pressure, and superheaters and reheaters should be thoroughly vented to remove air before nitrogen is admitted. All partly filled steam drums and superheater and reheater headers should be connected in parallel to the nitrogen supply. If nitrogen is supplied only to the steam drum, nitrogen pressure should be greater than the hydrostatic head of the longest vertical column of condensate that could be produced in the superheater.

Rather than maintaining the water in the boiler at normal operating level with a nitrogen blanket, it is sometimes preferred to drain the boiler completely, applying nitrogen continuously during the draining operation and maintaining a pressure of nitrogen greater than atmospheric throughout the draining and the subsequent storage.

WARNING!

If the boiler is drained under nitrogen, place warning signs on all drum manheads since entry by personnel could be fatal. Fresh air must be circulated before entry is attempted.

Fire Side

Fire side layup procedures are used to protect the fire side of a boiler during storage. The intent of fire side protection is not radically different from water side protection. The major problem on the fire side is to maintain dry clean surfaces and to avoid conditions where moisture can condense on metal surfaces and produce low pH acidic areas. Sulfur bearing fuels can produce ash deposits that are acidic in nature and can corrode external surfaces. These deposits can be hygroscopic, and in addition, if the temperature is below the dew point and condensation takes place, low pH conditions can occur in crevices formed by slag deposits on the waterwall tubes of the unit. It has been shown by some writers that the relative humidity of furnace air should be kept below 50% during idle periods. Low relative humidities can be obtained by the use of heat lamps, de humidification with circulation fans, and circulation of warm air. If the unit has a steam coil air heater, operation of this equipment is the safest and most effective way to furnish low humidity air.

Acidic-type external deposits should be removed from all surfaces prior to long term outages. Normally, high pressure water or steam lances are necessary to properly clean the tube surfaces.

After the tube surfaces are cleaned, they should be rinsed with an alkaline compound ($1\%Na_2CO_3$) to neutralize any residual acidic components from the ash deposits. After the final rinse, it is very important that all tube surfaces be thoroughly dried.

WARNING!

Moisture absorbing material has been placed in the waterside of this boiler. This material must be removed before boiler is filled with water or burner is fired. Inspect periodically and replace with new or regenerated material.

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PRESERVATION PROCEDURE FOR LONG TERM STORAGE OF ALL BOILERS

This procedure is applicable for all boilers made by Cleaver-Brooks, Inc. and to all environments where the boilers are stored. In extreme environmental cases supplementary conditions can be imposed. The procedure is valid for up to five (5) years.

When the client or purchaser has requested from Cleaver-Brooks, Inc. that the boiler units are delivered in a condition to allow for long term storage, Cleaver-Brooks, Inc. will perform a number of tasks to allow this storage to be performed successfully. Included are welding retainer plates in all risers and downcomers to allow for Nitrogen pressurization. Flanged nozzles will be closed off with B16.5 blind flanges, socket weld fittings will be closed from the inside of the unit.

This service will be performed at a charge to the client/purchaser and Cleaver-Brooks, Inc. will make sure that its equipment will be in optimum condition when leaving the plant.

After the equipment leaves the plant, the client/purchaser is responsible to perform all tasks described further in this procedure. Cleaver-Brooks, Inc. will not be held responsible if those tasks are not performed.

Principle of preservation

The preservation of the boiler unit is based on preventing oxidizing media to contact vital areas of the unit. The water surfaces of the drums and tubes are pressurized with inert media like nitrogen while the gas side surfaces are protected with moisture absorbing chemicals.

Water side surfaces

In order to protect the water side surfaces, devices will have to be installed that may require welding at the time of installation and removing of those devices after the storage period, in order to isolate the unit from the outside atmosphere. Detailed drawings of those devices and of the removal procedure will be part of the package that Cleaver-Brooks, Inc. will hand over to the client/purchaser at the time of shipment of the units. In almost all cases, internals in the units will only be partially installed to allow blanking off external

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connections. Detailed drawings allowing the client/purchaser to install the internals will also be available at the time of shipment. The client/purchaser will also receive (a) drawing(s) showing the devices installed and to be maintained during the storage to keep the unit pressurized with Nitrogen. As a rule, 5-7 psig (or approximately 0.5 bar) of nitrogen pressure must be maintained on the unit's internals during storage at all times. Check the unit initially after arrival and follow up on a daily basis for a few days until it is proven that the pressure is not dropping. After that, the unit should be checked on a weekly basis.

Gas side Surfaces

The gas side surfaces are protected with desiccant chemicals that absorb the water vapor. The units leave Cleaver-Brooks, Inc. with desiccant installed in the furnace. Cleaver-Brooks, Inc. cannot estimate when the desiccant will be saturated and the client/purchaser will be responsible to exchange the desiccant when required.

Inspection after long time storage

If a unit is stored for more than 6 months in dry condition without being installed or fired, all warranty on the unit will expire unless the unit is stored per this procedure.

After the storage, in order to re-instate the warranty, a visit from the Cleaver-Brooks, Inc. Quality Control Department is required to clear the unit.
The Cleaver-Brooks, Inc. Quality Control Department may demand additional cleaning of the unit in order to re-instate full warranty.

No unit stored over 18 months after delivery will receive full warranty without a separate warranty contract being entered into between the end user and Cleaver-Brooks, Inc.

Deferred installation of certain items on units stored long time

As mentioned above, some internals cannot be installed in order to facilitate the installation and removal of plugging devices. They will be shipped loose with the unit together with installation instructions.

Refractory material is not installed in boilers put in storage since it will deteriorate if not fired within 6 months after installation and it could cause

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corrosion of the metal on which it is installed. The material cannot be shipped loose because of its limited shelf life. The client will have to re-order the material when he decides to install the boiler. The material may be subject to a price increase and freight charges.

Comments regarding handling the units

Some boilers are shipped with a special frame allowing to lay the units on their side during transportation. They can be stored either at the location of shipment or at the destination location in that position for a short period of time. Putting the unit on its side puts stresses on components for which they were not designed. Although Cleaver-Brooks, Inc. takes these stresses into account during the design stage, they are only evaluated for short durations. Long term storage of the units in that position could lead to deforming of certain components and is not allowed. After the units are delivered to the jobsite they need to be put in upright position within 7 days.

This MSDS is for reference if desiccants were used during storage and shipment of the boiler.

Material Safety Data Sheet

Material Name: Desi Pak

*** Section 1 - Chemical Product and Company Identification ***

Distributor Information

Uline
2200 S. Lakeside Dr
Waukegan, IL 60085

Phone: 847-473-3000
Fax: 847-473-5157

*** Section 2 - Hazards Identification ***

Emergency Overview

Poses little or no immediate hazard.

Potential Health Effects: Eyes

Route of exposure unlikely. Dust may cause a mechanical irritation which can scratch the eye.

Potential Health Effects: Skin

No adverse effects expected

Potential Health Effects: Ingestion

Non-toxic by ingestion. Packets or canisters may pose a choking hazard. Keep away from children and pets.

Potential Health Effects: Inhalation

Route of exposure unlikely. This material is normally packaged and contained in a pouch, bag or canister. If the container is opened, prolonged or repeated inhalation of high dust concentrations may cause lung damage.

HMIS Ratings: Health: 0 **Fire:** 0 **HMIS Reactivity** 0

Hazard Scale: 0 = Minimal 1 = Slight 2 = Moderate 3 = Serious 4 = Severe * = Chronic hazard

*** Section 3 - Composition / Information on Ingredients ***

CAS #	Component	Percent
1302-78-9	Bentonite	25-99
Not Available	Pouch, Bag, Canister, Stopper, or Cap	1-75
14808-60-7	Quartz	<0.5

*** Section 4 - First Aid Measures ***

First Aid: Eyes

Do not rub eyes. Flush with lukewarm, gently flowing water for 5 minutes or until the particle/dust is removed, while holding the eyelid(s) open. Obtain medical attention.

First Aid: Skin

Wash with soap and water.

First Aid: Ingestion

Normally not needed. If large quantities are ingested, call your local Poison Control Center (1-800-222-1222 in the U.S.).

First Aid: Inhalation

Normally not needed. If exposed to excessive levels of dust or fumes, remove to fresh air and seek medical attention of cough or other symptoms develop or persist.

*** Section 5 - Fire Fighting Measures ***

General Fire Hazards

See Section 9 for Flammability Properties.
Material is not flammable

Hazardous Combustion Products

Not Determined.

Extinguishing Media

Use extinguishing agent applicable to surrounding fire.

Fire Fighting Equipment/Instructions

As in any fire, wear self-contained breathing apparatus operated in pressure demand mode, (NIOSH approved or equivalent) and full protective gear.

Material Safety Data Sheet

Material Name: Desi Pak

NFPA Ratings: Health: 0 **Fire:** 0 **Reactivity:** 0
Hazard Scale: 0 = Minimal 1 = Slight 2 = Moderate 3 = Serious 4 = Severe

*** Section 6 - Accidental Release Measures ***

Containment Procedures
None
Clean-Up Procedures
With shovel or scoop, place material into appropriate container.
Evacuation Procedures
None
Special Procedures
None

*** Section 7 - Handling and Storage ***

Handling Procedures
Use of proper hygiene practices in the workplace is recommended.
Storage Procedures
Store in a dry area.

*** Section 8 - Exposure Controls / Personal Protection ***

A: Component Exposure Limits
Quartz (14808-60-7)
ACGIH: 0.025 mg/m3 TWA (respirable fraction)
OSHA: 0.1 mg/m3 TWA (respirable dust)
NIOSH: 0.05 mg/m3 TWA (respirable dust)

Engineering Controls
If user operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.
PERSONAL PROTECTIVE EQUIPMENT
Personal Protective Equipment: Eyes/Face
Follow facility guidelines.
Personal Protective Equipment: Skin
Use of proper hygiene practices in the workplace is recommended.
Personal Protective Equipment: Respiratory
Use local exhaust if dusting occurs. Good general ventilation is adequate in the absence of dusts.
Personal Protective Equipment: General

*** Section 9 - Physical & Chemical Properties ***

Appearance:	Desiccant pack	**Odor:**	None
Physical State:	Solid	**pH:**	ND
Vapor Pressure:	ND	**Vapor Density:**	ND
Boiling Point:	ND	**Melting Point:**	ND
Solubility (H2O):	ND	**Specific Gravity:**	ND
Evaporation Rate:	ND	**VOC:**	ND
Octanol/H2O Coeff.:	ND	**Flash Point:**	ND
Flash Point Method:	ND	**Upper Flammability Limit (UFL):**	ND
Lower Flammability Limit (LFL):	ND	**Burning Rate:**	ND
Auto Ignition:	ND		

*** Section 10 - Chemical Stability & Reactivity Information ***

Chemical Stability
This is a stable material.

Chemical Stability: Conditions to Avoid
None
Incompatibility
None
Hazardous Decomposition
Not Determined
Possibility of Hazardous Reactions
Will not occur.

*** Section 11 - Toxicological Information ***

Acute Dose Effects
A: General Product Information
No information available for the product.
B: Component Analysis - LD50/LC50
Bentonite (1302-78-9)
Oral LD50 Rat >5000 mg/kg

Quartz (14808-60-7)
Oral LD50 Rat 500 mg/kg

Carcinogenicity
A: General Product Information
No information available for the product.
B: Component Carcinogenicity
Quartz (14808-60-7)

ACGIH:	A2 - Suspected Human Carcinogen
NIOSH:	potential occupational carcinogen
NTP:	Known Human Carcinogen (Select Carcinogen)
IARC:	Monograph 68 [1997] (listed under Crystalline silica inhaled in the form of quartz or cristobalite from occupational sources) (Group 1 (carcinogenic to humans))

*** Section 12 - Ecological Information ***

Ecotoxicity
A: General Product Information
Low hazard for usual industrial or commercial handling.
B: Component Analysis - Ecotoxicity - Aquatic Toxicity
Bentonite (1302-78-9)

Test & Species	Conditions
96 Hr LC50 Salmo gairdneri	8.0-19.0 g/L
96 Hr LC50 Oncorhynchus mykiss	19000 mg/L [static]

*** Section 13 - Disposal Considerations ***

US EPA Waste Number & Descriptions

Component Waste Numbers
No EPA Waste Numbers are applicable for this product's components.
Disposal Instructions
This product, if discarded as sold, is not a Federal RCRA hazardous waste. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations.
See Section 7 for Handling Procedures. See Section 8 for Personal Protective Equipment recommendations.

*** Section 14 - Transportation Information ***

US DOT Information
Shipping Name: Not Regulated

*** Section 15 - Regulatory Information ***

US Federal Regulations

Component Analysis

None of this products components are listed under SARA Section 302 (40 CFR 355 Appendix A), SARA Section 313 (40 CFR 372.65), or CERCLA (40 CFR 302.4).

State Regulations

Component Analysis - State

The following components appear on one or more of the following state hazardous substances lists:

Component	CAS	CA	MA	MN	NJ	PA	RI
Quartz	14808-60-7	No	Yes	Yes	Yes	Yes	Yes

The following statement(s) are provided under the California Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65):

WARNING! This product contains a chemical known to the state of California to cause cancer.

Component Analysis - WHMIS IDL

No components are listed in the WHMIS IDL.

Additional Regulatory Information

Component Analysis - Inventory

Component	CAS #	TSCA	CAN	EEC
Bentonite	1302-78-9	Yes	DSL	EINECS
Quartz	14808-60-7	Yes	DSL	EINECS

*** Section 16 - Other Information ***

Other Information

The information herein is presented in good faith and believed to be accurate as of the effective date given. However, no warranty, expressed or implied, is given. It is the buyer's responsibility to ensure that its activities comply with Federal, State or provincial, and local laws.

Key/Legend

EPA = Environmental Protection Agency; TSCA = Toxic Substance Control Act; ACGIH = American Conference of Governmental Industrial Hygienists; IARC = International Agency for Research on Cancer; NIOSH = National Institute for Occupational Safety and Health; NTP = National Toxicology Program; OSHA = Occupational Safety and Health Administration., NJTSR = New Jersey Trade Secret Registry.

CleaverBrooks NATCOM

ENGINEERED BOILER SYSTEMS GROUP

PRE-COMMISSIONING CHECK LIST

CUSTOMER: **JOB LOCATION:**

JOB NUMBER: **DATE:**

ITEMS TO BE COMPLETED BEFORE ACTUAL START-UP

THIS DOCUMENT MUST BE COMPLETED, SIGNED, AND RETURNED BY PERSON(S) RESPONSIBLE FOR WORK COMPLETION PRIOR TO ANY FIELD SERVICE SCHEDULING.

Any item not completed prior to field service person arriving on site, which cause delays, will be billed at the standard service rate, plus travel and living expenses.

Any delays attributed to contractor, purchaser or final user of over two (2) days will require a second trip. The first trip will be billed totally to the contractor, purchaser or final user at the standard service rate, plus travel and living expenses.

ITEMS #	ITEMS STATUS AND COMMENTS	COMP. %	EST.COMP DATE	SIGN
1.	Necessary operational permits acquired and on site. COMMENTS:			
2.	Operation and Instruction Manuals on site. COMMENTS:			
3.	Furnace area clean COMMENTS:			
4.	No damage in boiler refractory due to shipment. COMMENTS:			
5.	Hydro boiler (if required). COMMENTS:			
6.	Clean and check operations of all traps and strainers. COMMENTS:			
7.	Boil-out chemicals at job site. COMMENTS:			

ITEMS #	ITEMS STATUS AND COMMENTS	COMP. %	EST.COMP DATE	SIGN
8.	High pressure water for drum cleaning after boil-out, large volume. **COMMENTS:**			
9.	Proper disposal of boil-out water. Permits as required. **COMMENTS:**			
10.	All breaching and duct work seal welded or bolted with gaskets. **COMMENTS:**			
11.	All field wiring completed and checked. **COMMENTS:**			
12.	All instrumentation and associated sensing line installed **COMMENTS:**			
13.	Electrical power supply to fan available (with proper voltage). **COMMENTS:**			
14	Electrical power supply to all controls panels available (with proper voltage). **COMMENTS:**			
15.	Feedwater piping completed, purged and insulated. **COMMENTS:**			
16.	Fuel oil piping completed, purged, primed and insulated **COMMENTS:**			

ITEMS #	ITEMS STATUS AND COMMENTS	COMP %	EST.COMP DATE	SIGN
17.	Main gas PRV (pressure reducing valve) installed per manufacturer's recommendations. **COMMENTS:**			
18.	Necessary equipment to maintain constant fuel supply pressures. **COMMENTS:**			
19.	Proper fuel supply pressures. **COMMENTS:**			
20.	Pilot and main gas piping completed, purged and pressure tested. **COMMENTS:**			
21.	Steam piping completed, purged and insulated. **COMMENTS:**			
22.	Atomizing steam piping completed, purged and insulated. **COMMENTS:**			
23.	Proper instrument and plant air supply pressure and capacity available. **COMMENTS:**			
24.	Necessary controlled steam vents for start-up calibration and performance testing. **COMMENTS:**			
25.	Plant air connections completed, purged and pressure tested. **COMMENTS:**			
26.	Instrument air piping to instruments completed. **COMMENTS:**			

ITEMS #	ITEMS STATUS AND COMMENTS	COMP. %	EST.COMP DATE	SIGN
27.	Necessary calibrated instruments for efficiency test (if required). COMMENTS:			
28.	Necessary equipment ladders, stands, etc. to reach burner/boiler adjustments. COMMENTS:			
29.	Safety valves and discharge piping installed. COMMENTS:			
30.	Feedwater available for capacity testing without any condensate returning. COMMENTS:			
31.	Fuel oil analysis to verify compliance with project specifications (if required). (Copy of report should be available upon request). COMMENTS:			
32	Cooling air piping to viewports, flame scanners installed COMMENTS:			

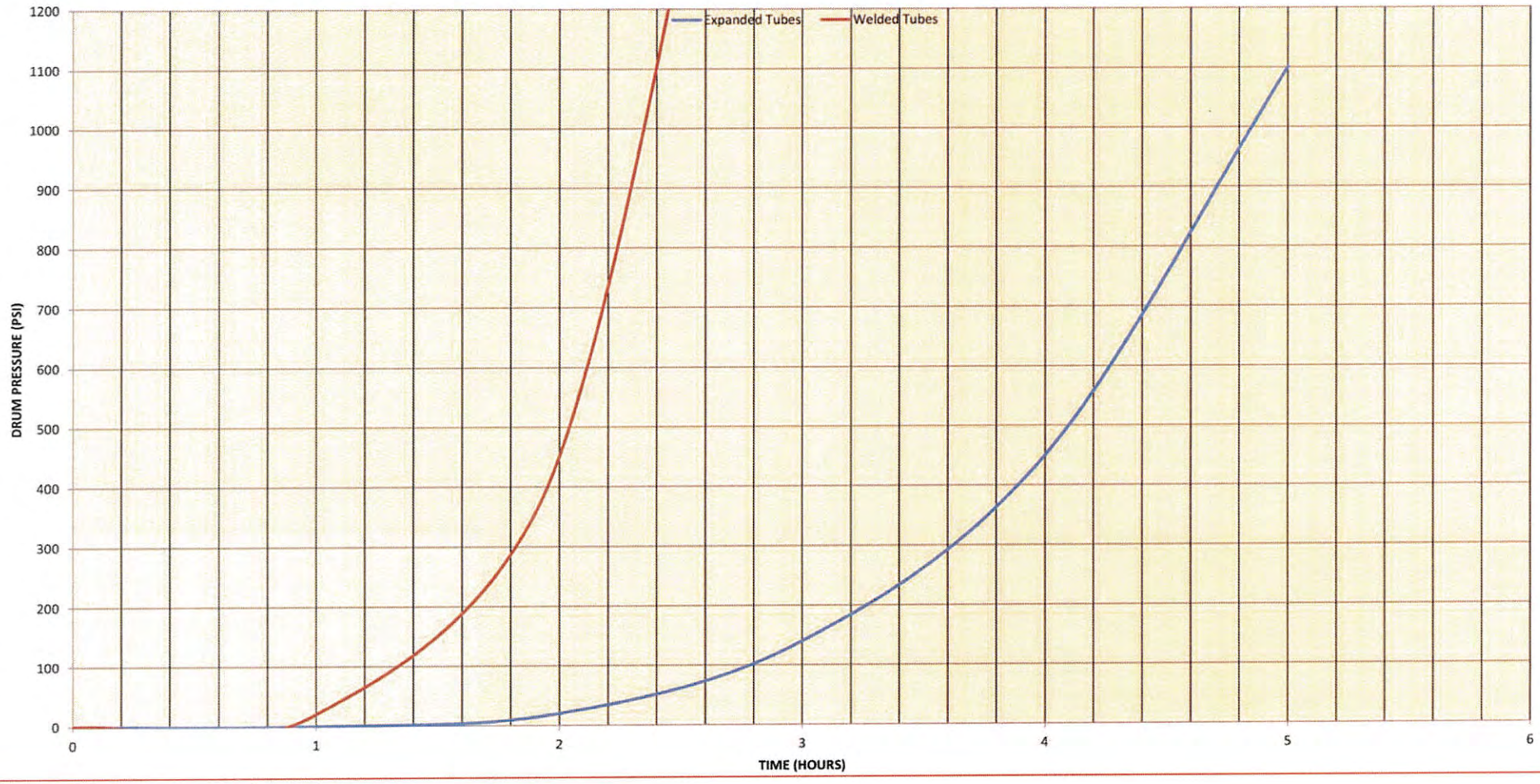
Checked by: _____

Company: _____

Date: _____

CleaverBrooks

EBS IWT STARTUP CURVE



NOTES:

1. Heat input should be cycled (If required) until steady steaming is established.
2. A minimum steam flow should be maintained through the superheater to prevent overheating. Monitor the outlet steam temperature.
3. Operator should be thoroughly familiar with and follow the instructions in the Operation & Maintenance Manual.
4. This suggested start-up curve is for quick reference and cannot be substitute to the detailed instructions in the O & M Manual.
5. Water temperature should be a minimum of 70°F.
6. Warm-up rate not to exceed 100°F per hour.