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Note 1: Operation

Startup, Adjustments, Shutdown and trouble shooting will be found in the Burner portion of the manual. (If applicable)

Section 1: General

A: Contact Information

Johnston Boiler Company
300 Pine Street
Ferrysburg, MI 49409

SALES

Boiler / Burner

Pat Baker

Phone 616-638-4737

Fax 616-842-1854

Email pbaker@johnstonboiler.com

Thom Parker

Phone 616-842-5050 ext 314

Fax 616-842-1854

Email tparker@johnstonboiler.com

Deaerators (ancillary)

Rick Slater

Phone 616-842-5050 ext 336

Fax 616-842-1854

Email rslater@johnstonboiler.com

SERVICE

Technical Support Or Field Service

Ed Wessel

Phone 616-842-5050 ext 311

Fax 616-846-6380

Email ewessel@johnstonboiler.com
or service@johnstonboiler.com

PARTS

Spare or Replacement

Donna Utzman

Phone 616-842-5050 ext 317

Fax 616-846-6380

Email dutzman@johnstonboiler.com

Section 1:

B. Introduction

Thank you for purchasing a series PFT Boiler from Johnston Boiler Company.

All Johnston Boiler products are designed and manufactured to give excellent, efficient performance over a long period of time. All items supplied were chosen because of their ability to give high quality performance. Proper operating and maintenance procedures must be followed at all times to ensure a high degree of protection and safety. Operation of this equipment should not be considered free from all dangers inherent to operating a steam/hot water vessel with the firing of a combustible fuel.

The operator is solely responsible for properly maintaining the equipment. No amount of documented instruction can take the place of intelligent thinking and consistent safe practices. This manual is not intended to relieve the operator of the responsibility of proper operation.

The operator must be familiar with all components and operations of the level, pressure and temperature controls as well as the fuel burning equipment. Identify and locate each component of your system.

C. General Boiler Description

Your boiler is termed Packaged Firetube (PFT), and is intended to be supplied as a packaged system complete with fuel fired burner, pressure and level controls, as well as electronic control and monitoring system. All Johnston boilers are built to strict ASME guidelines whether it is Section 1 or Section 4 design.

The boiler is of a wet back design with a fully submerged combustion chamber and firing tube. It may be of a two, three or four pass arrangement depicted by the number of tube passes within one common shell. As a standard, Johnston builds these vessels with control connections on both sides. An ample amount of handholes are strategically placed and all vessels are equipped with lifting lugs, 12x16 manway for water side access and a large door for access to the combustion firetube area. At both ends there will be full tube access swing doors on double pivot hinges. The tube access doors will be lined with high temperature insulation (not refractory). The shell and exposed head areas will be covered with 2" insulation and galvaneal sheet metal jacket.

D. General Burner Description

Refer to the proper section for the size, type and description of fuel burning equipment supplied. All Johnston boilers supplied with a factory installed burner shall be factory test fired when possible.

E. Customer Specific Drawings

The drawings, diagrams and bill of materials placed at the back of this manual are specific to the customer's contract with Johnston Boiler Company. The inserted drawings are the jurisdictional design of the system provided. All other information provided in this manual may or may not depict actual scope of supply.

Section 1:

F. Warranty General Information

Products manufactured by the Company are warranted to be free from defects in material and workmanship under normal use and service for a period of one (1) year from start-up but not to exceed eighteen (18) months from shipment or completion of manufacture. Components which are purchased by the Company and resold without further processing by the Company are not covered by the Company's warranty, but the Company shall pass on to the Buyer whatever warranty the Company receives from the manufacturer of such products. Components which are supplied by the Company but field installed by others are not covered unless installation has been inspected and accepted by an authorized Johnston Representative. The Company will repair or replace, at its option, its products which prove to be defective within the warranty period F.O.B. Company's factory. The Company's warranty shall be voided by any repair, alteration or modification by persons other than the Employees of the Company or those expressly authorized by the Company to make repairs, or by any abuse, misuse or neglect of the products or by use not in accordance with the Company's published instructions. The remedies for any failure of the Company's products to meet its warranty specified herein shall be those remedies as a condition of sales irrespective of the theory upon which any claim might be based, including negligence, breach of contract, or strict liability. THIS PARAGRAPH CONTAINS THE COMPANY'S SOLE WARRANTY. THE COMPANY MAKES NO IMPLIED WARRANTY AND THERE IS NO IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

NOTE:

NOTE:

It is the responsibility of the individual, company, organization, or institution receiving a new boiler, or packaged system to inspect the shipment for damage, alteration or missing components upon initial receipt. Transporters insist that all deficiencies be noted on the shipping documentation prior to acceptance. Johnston will not accept responsibility for shipping damages or claims against transporters.

NOTE:

Each Johnston Boiler is shipped with an order specification sheet, bill of materials, piping diagram, wiring diagram, and other reference materials specific to this job. A thorough understanding of and familiarity with these documents is required prior to systems installation, commissioning, operation or trouble shooting.

Section 1:

G. Parts and Service Policy

Johnston Boiler Company markets their products through a distribution system, made up of independent manufacturers' representatives. For parts and service requirements, contact your authorized Johnston representative.

H. Warranty Claims and Material Return

Johnston Boiler Company's warranty on parts, whether purchased as a component part of a new boiler or as a replacement part, is as described under the "WARRANTY AND EXCLUSION OF IMPLIED WARRANTIES" paragraph of Johnston's Standard Terms and Conditions of Sale. Johnston's parts warranty claim policy and return procedure is as follows:

It is recognized that often a warranty replacement part may be needed in advance of returning the claimed defective part for warranty consideration. Johnston Boiler Company can accommodate this situation. In order for Johnston to advance a warranty replacement part, a written purchase order must be issued to Johnston Boiler Company in the amount of the selling price for the replacement part and to cover any prepaid shipping charges that Johnston may incur. Upon receipt of the purchase order, and subject to availability of the replacement part, the advance warranty replacement part will then be shipped in the manner requested. At this same time, Johnston will issue and submit an invoice covering the part and freight charge.

Johnston will include a pre-numbered, 3-part Return Authorization Tag (Exhibit A) with the shipment of an advance warranty replacement part. This tag must be completed by someone knowledgeable of the claimed defect in the part to be returned. The green copy of the tag, which reads "TO BE RETAINED BY PARTY MAKING RETURN", is to be kept by the party making the return. The remaining two (2) copies of the tag yellow "JBC RECEIVING GIVE TO JBC SERVICE/PARTS" and buff (hard copy) "ATTACH TO PART BEING RETURNED (ALSO TO INCLUDE YELLOW COPY): are to be attached to the claimed defective part. The part is then to be returned to Johnston Boiler Company, freight prepaid (collect freight shipments will not be accepted), for warranty consideration.

Upon Johnston's receipt of the claimed defective part, the part will be reviewed for warranty consideration. A decision to accept or reject the warranty claim will be made. On parts that were manufactured by Johnston, this decision will be made by Johnston. On parts that were purchased by Johnston, the claimed defective part will be returned by Johnston to the actual manufacturer of the part, to be reviewed for warranty consideration. Any such other manufacturer will make the decision to accept or reject the warranty claim. Johnston will forward this decision on to its customer, the same as with Johnston's own decision on warranty claims covering any parts it manufactures. Johnston will notify its customer of the decision regarding a parts warranty claim in writing.

On accepted parts warranty claims, Johnston Boiler Company will then cancel its invoice covering shipment of the advance warranty replacement part, less any prepaid shipping charges. Any prepaid shipping charges are due and payable by a customer, in accordance with the terms of Johnston Boiler Company's warranty.

On rejected parts warranty claims, Johnston will include in its written notification to a customer, the reason why the warranty claim was rejected. On rejected parts warranty claims, Johnston's invoice covering the warranty replacement part, whether advanced or otherwise is due and payable in the full amount by the customer.

All claimed defective parts must be returned to Johnston Boiler Company for warranty consideration no later than thirty (30) days after the advance warranty replacement part was shipped by Johnston.

On non-warranty claim parts returns, authorization to make any such return must be received from Johnston prior to making the actual return shipment. Johnston will mail to the customer the pre-numbered, 3-part Return Authorization Tag. (Exhibit A) This tag is then to be completed and handled in the same manner as a warranty claim.

Section 1:

EXHIBIT A

Johnston Boiler Company
300 Pine Street
Ferrysburg, MI 49409

Return
Freight
Prepaid To:

Johnston Boiler Company

Return Authorization No _____

S.O. # _____ Serial # _____

Model (or Catalog) # _____

Job Name: _____

Location: _____

Date of Return: _____ By: _____

This Item is being returned for the following consideration:

() Credit () Warranty Replacement

() Credit – Warranty Replacement Already Received

Reason for Return: _____

JBC RETURN AUTHORIZATION

Section 1:

J. Model Description Key

The Johnston boiler is a steam or hot water packaged firetube boiler, ranging in size from 50 to 2,500 horsepower, 15# to 350# design pressure, 3 or 4 pass, of welded steel construction with submerged rear combustion chamber. The package consists of a pressure vessel, base frame, forced draft burner, fuel train(s), control panel, power panel and miscellaneous boiler trim.

Your Johnston boiler will be assigned a model number made up of the following:

PFT	A	600	-	4	LG	150	S
1	2	3	-	4	5	6	7

1. PFT, PFX = Packaged Firetube (Boiler), XID Packaged Firetube
2. Type of Burner =
 - A = Johnston "A" Burner
 - J = Johnston "J" Burner
 - I = Industrial Combustion Burner
 - JO = Ohio Special with "J" style burner
 - AO = Ohio Special with "A" style burner
 - X = No burner
 - P = Power Flame burner
 - G = Gordon Piatt burner
 - W = Webster burner
 - S = Johnston "S" burner
3. Horsepower = 50 through 3,000
4. Number of passes = 2, 3 or 4
5. Fuels =
 - H = Heavy oil
 - M = Medium oil
 - L = Light oil
 - G = Natural gas
 - DG = Digester gas
 - P = Propane or Propane-Air mix
 - X = Special or no burner supplied at factory
6. Design Pressure = 15 to 350
7. Type of Boiler =
 - S = Steam
 - W = Hot Water

Section 2: Components

A. Component Overview –General Trim Items Fig 2.1, Fig 2.2

Johnston Series PFT Boilers generally include the following trim items. Where the word “steam” is indicated, the device commonly applies to steam boilers only.

Low Water Cutoff	Stops the burner on a low water condition. Burner restarts when normal water is achieved.	Safety Relief valve(s)	Boiler shell mounted device to vent excess steam/water when boiler pressure/temperature is exceeded.
Aux. Low Water Cutoff	Stops the burner on a low water condition. Burner restarts when normal water is achieved and manual intervention is involved (manual reset).	Feedwater modulating control valve (steam)	On signal from level controller, modulates open/close to allow condensate to flow in to boiler.
Optional: Boiler Level Controller (steam)	Signals feed water valve to modulate open/close as necessary to maintain proper water level.	Quick opening blowoff valve (steam)	Lever handled valve piped to bottom of boiler to allow quick discharge of condensate and contaminants.
Optional: Boiler High Water Alarm (steam)	Signals the operator of a high level in the boiler. If desired, could stop the burner as well.	Slow opening blowoff valve	Wheel handled valve piped to bottom of boiler to allow slow discharge of condensate and contaminants.
Operating Limit Controller	Restricts the boiler from over pressure or temperature. Stops the burner on high condition, restarts when boiler returns to normal.	Continuous blowoff control valve (steam)	Position indicating hand wheel needle valve to meter the discharge of condensate at the top of the boiler.
High Limit Control	Restricts the boiler from over pressure or temperature. Stops the burner on high condition, restarts when boiler returns to normal and manual intervention is involved (manual reset).	Continuous blowoff control valve (steam)	TDS manual control. Position indicating hand wheel needle valve to meter the discharge of condensate at the top of the boiler.
Modulating press or temp. controller	Signals burner to adjust firing rate on the basis of the boilers current operating pressure/temperature.	Automatic continuous blowoff system (steam)	TDS automatic control. Controller, electric valve and conductivity probe. Controller opens/closes valve on basis of input signal from probe.
Pressure or combination press altitude gauge	Direct reading gauge located close to the limit controls. Boiler monitor.	Steam non-return valve (steam)	Combination stop/check valve to isolate and back flow prevention.
Low Fire Hold limit control	Restricts the burner from firing above “low” prior to water temperature achieving set temperature.	Steam stop valve (steam)	Stop gate valve to isolate boiler.
		Sight glass	Visual indication of water level.
		Tri-cocks	When opened, gives secondary indication of water level.

Section 2:
Steam Boiler Trim

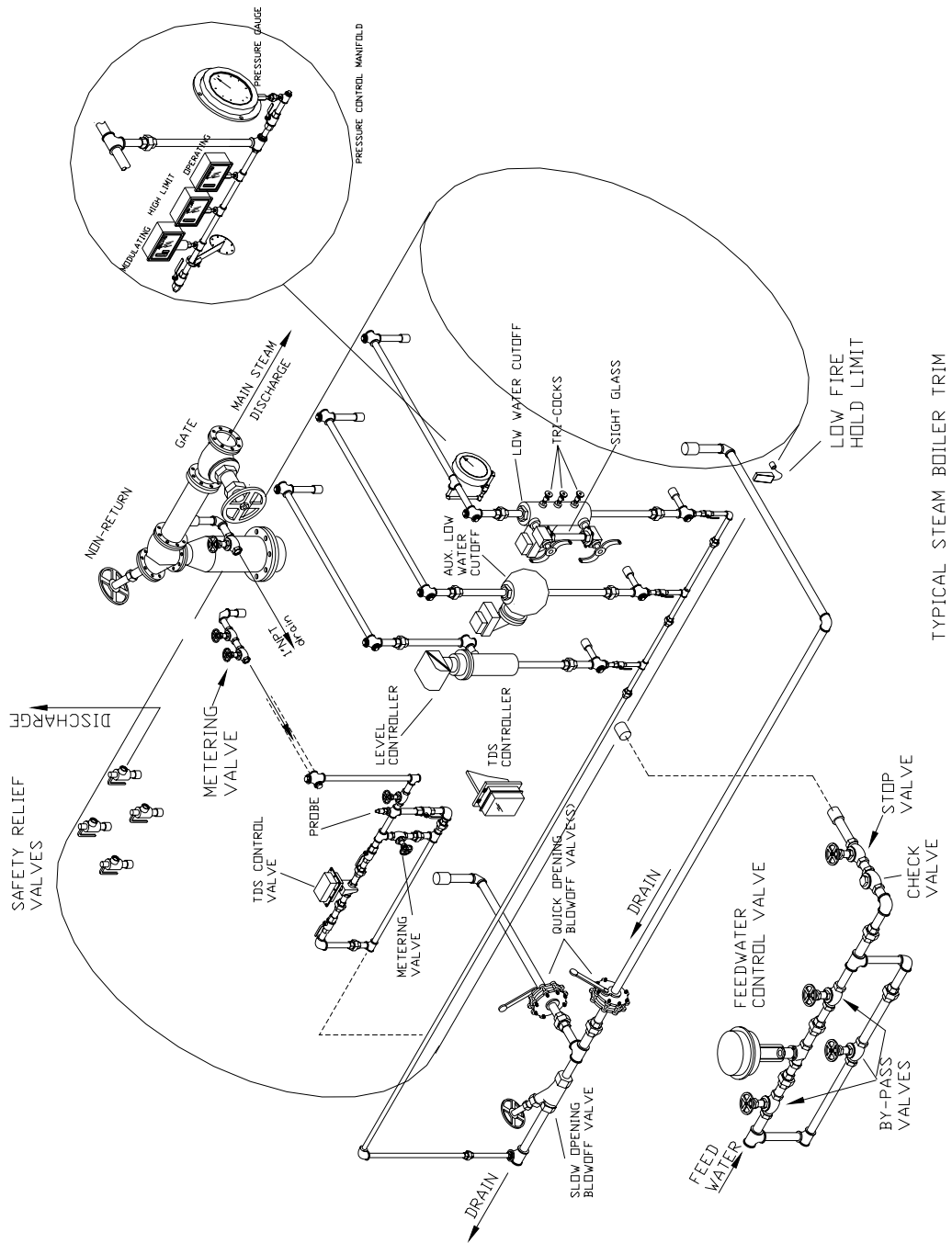


FIGURE 2.1

Section 2:

Water Boiler Trim

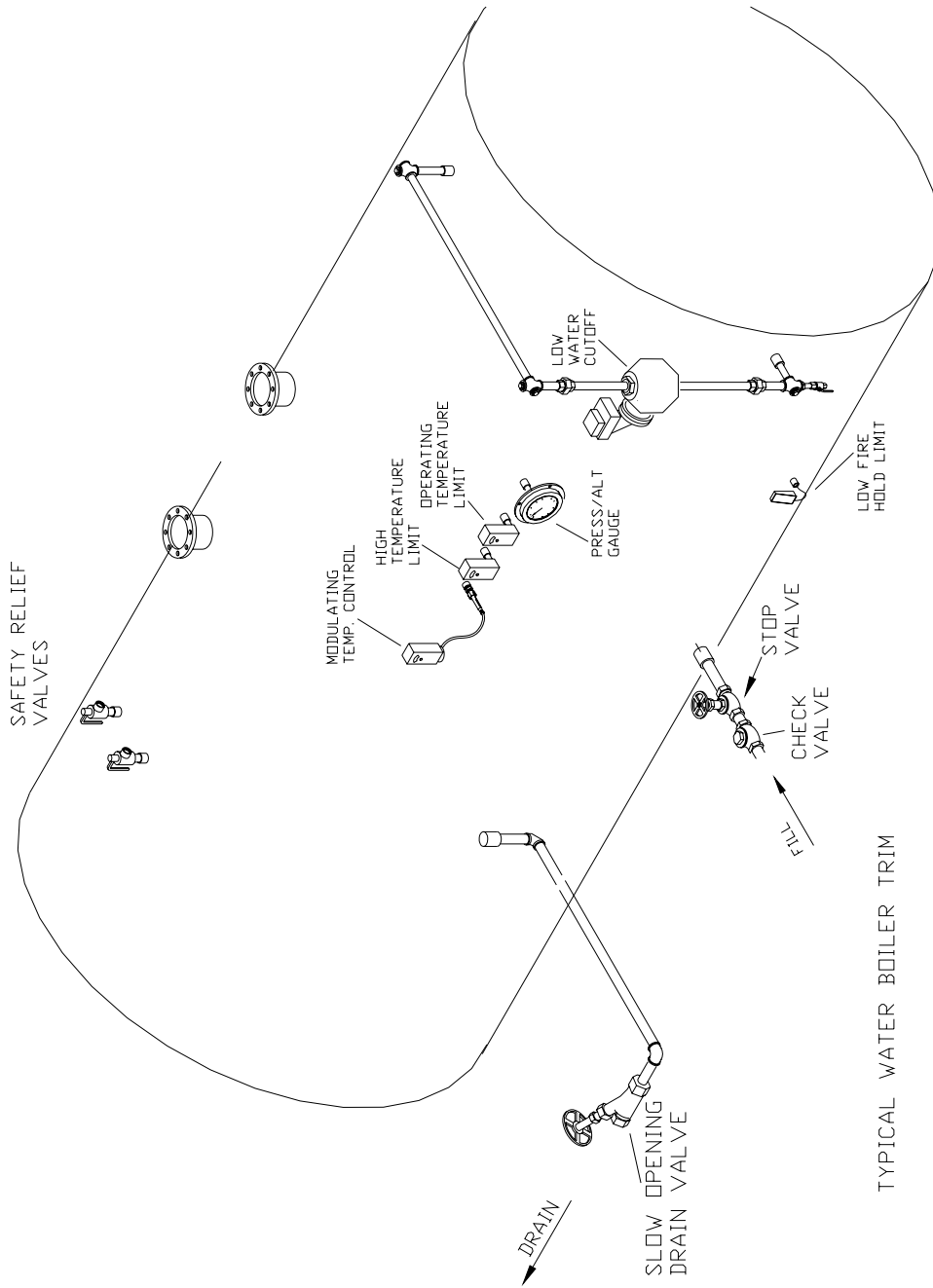
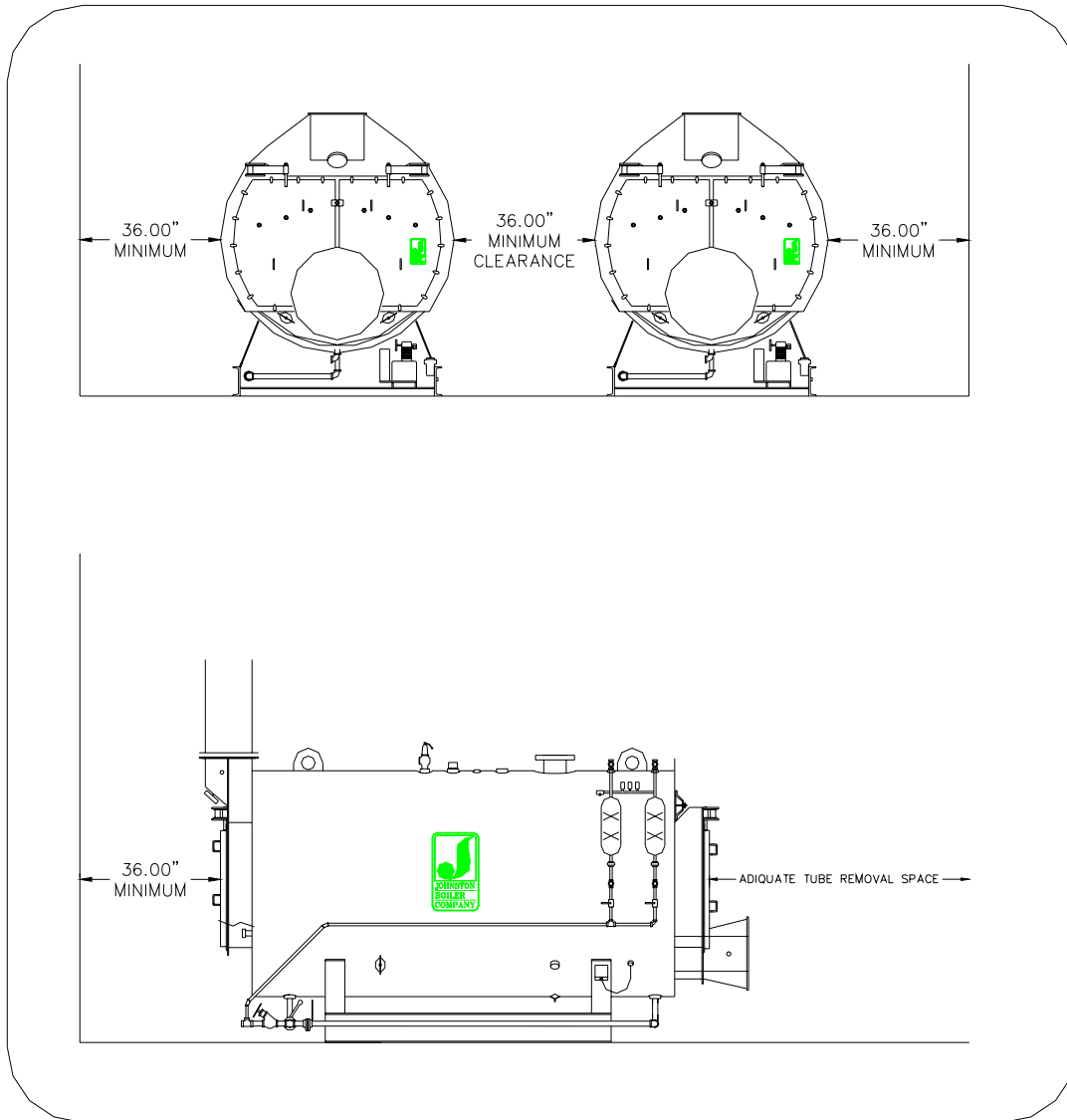


FIGURE 2.2

Section 3: Installation

A. General

The following are general recommendations for installing a Johnston Packaged Boiler. Project plans and state and local code requirements must also be followed. These legal requirements take precedence over information found in this manual.



B. Installation Recommendations

The boiler should be set on a raised concrete pad. The boiler should be level and its base frame should be grouted to the raised concrete pad. A 36" aisle space at the sides and to the rear of the boiler is recommended. Adequate space for boiler tube removal and replacement should be provided to the front of the boiler. Refer to the specified boiler size requirements, in this regard.

The flue gas outlet connection on a Johnston Boiler is only intended to support a limited boiler stack, or breeching. The minimum stack diameter for a given size boiler should be adhered to.

Section 3:

Where a breeching is used, a round breeching is preferred. If a rectangular breeching is used, stiffeners should be provided in large flat areas of the breeching, not only for strength, but to minimize the possible vibration and noise that may be experienced from using a rectangular breeching.

If two or more boilers are installed in a common breeching, the breeching size should get progressively larger from the boiler farthest from the stack to the boiler nearest the stack. This is done to accommodate the additional volume of flue gas from one boiler to the next.

A rain cap is recommended on a stack connected directly to the boiler. The rain cap should be mounted no less than the diameter of the stack, and above the end of the stack.

Boiler feed, steam or water, fuel piping and electrical supply lines should be properly installed to the boiler. It is recommended that feedwater and fuel supply lines be properly valved, so the supply lines to the boiler can be shut off when it is not in use or when preventive maintenance or repairs to the boiler are being made. A "dirt trap" should be installed in the gas supply line, just prior to entering the main gas train of the boiler. A means to disconnect and lockout the power supply to the boiler control panel should also be provided. Installation of boiler feedwater, fuel and electrical power supply piping and lines should be checked, so as not to interfere with operation of any component part of the boiler, or interfere with the ability to perform preventive maintenance or make repair. Special attention should be given to making sure that no piping or lines interfere with the boiler fluebox doors.

Warning

Very often boiler safety relief valves are removed from the boiler, following factory testing of the boiler, just prior to shipment. These safety relief valves must be properly reinstalled on the boiler, **using only a safety valve wrench**. Using a conventional wrench often damages safety relief valves. This type of damage is not covered under the boiler warranty. All safety relief valves should be piped to a safe point of discharge. Safety relief valve discharge piping should have an internal area equal to or greater than the internal area of the valve outlet. The discharge piping should be arranged and installed so that no strain is imposed on the safety relief valve

Warning

All blowoff and blowdown valves, including any Johnston supplied piping, whether water column, surface/continuous or bottom, should be piped, or further piped, properly and to a safe point of discharge. If they are piped into a blowdown separator, the blowdown line should be properly valved, so the boiler is capable of being completely drained.

C. Boiler Room Air Supply

The starting point in any combustion system is the supply of fresh air. To avoid serious problems, the boiler must have an adequate supply of fresh air and a supply system that does not affect the boiler operation.

Section 3:

How much air is required?

In general, the following formulas have been developed to determine the amount of combustion air required for any boiler room with a package firetube boiler firing gas or oil fuels:

$$\text{Combustion Air} = \text{HP} \cdot 8 \frac{\text{ft}^3}{\text{min} \cdot \text{HP}}$$

$$\text{Ventilation Air} = \text{HP} \cdot 2 \frac{\text{ft}^3}{\text{min} \cdot \text{HP}}$$

$$\text{Total Air Required} = \text{HP} \cdot 10 \frac{\text{ft}^3}{\text{min} \cdot \text{HP}}$$

HP refers to the total maximum boiler horsepower in the boiler room.

These calculations are adequate for installations up to 1000 feet above sea level. For any installation above 1000 feet, add 3% air for each 1000 feet.

What size of opening to the outside is required?

An adequate, proper and consistent supply of fresh air must be supplied into the boiler room for burner combustion air. A rule of thumb is to provide four to six square inches of open, unrestricted area for every boiler horsepower. Example: For a 75 HP boiler, 300 to 450 square inches of open unrestricted area are recommended.

The size of the fresh air inlet openings and their location are very important. There should be a minimum of two permanent air supply openings in the walls of the boiler room. Whenever possible, they should be at opposite sides of the boiler room and no higher than 7 feet above the floor. This will promote mixing with the air already in the boiler room, proper cooling of the boilers, and tempering of potentially colder outside air prior to its entering the burner for combustion.

The air inlets should be provided with some type of weather protection, but should never be covered with a fine mesh wire screen. This type of covering results in poor air flow and is subject to clogging by dust, dirt, paper, and other small items.

To determine the net free open area required for an opening, divide the total air required (in cubic feet per minute) by the allowable velocity at the opening, from the table below.

Acceptable Air Velocities in Boiler Room	
0-7 ft above floor	250 feet per minute
Above 7 ft above floor	500 feet per minute

The minimum opening to the outside should be one square foot

Air Ducting

In some applications, the boiler room is located in a building such that it has no outside walls. Many of these applications do not have sufficient excess makeup air in the factory to allow for combustion air requirements. In these cases, there are two possible solutions:

Section 3:

1. Ducting fresh air into the boiler room. Where this is required, the general rules for the size of the wall opening can be used to determine the size of the ducting and wall opening in the boiler room. In addition, the pressure drop through the duct must never exceed 0.05" w.c.
2. Ducting fresh air directly into the boiler. This method of air supply should be avoided whenever possible. The disadvantages of this type of system far exceed any perceived advantages. If used, the ducting becomes a part of the boiler system and can affect the stability of combustion due to varying weather conditions, wind direction and velocity, humidity, and temperature. Changes in temperature can lead to massive CO production, soot formation, and unstable, unsafe combustion.

If direct ducting is to be used, we suggest the following steps be followed:

1. Each boiler has its own, completely separate, fresh air ducting and exhaust stack to minimize combustion problems.
2. Boiler directly connected to fresh outside air ducts must be checked for proper combustion adjustment and operation every three months by a certified package firetube boiler specialist.
3. The duct work supplying the fresh air to the boiler must be sized so that it has a maximum pressure drop of 0.05" w.c. at maximum flow.
4. The fresh air supply should have an electric, hot water, or steam heater to temper cold outside air to at least 50 deg F.
5. If the application is utilizing a low emission with flue gas recirculation, **do not** use direct ducted outside air. The potential problems associated with a standard burner are intensified with a low emission burner.

D. Stack Design and Package Boiler/Burner Operation

Firetube boiler/burner packages with the exhaust stack and breeching attached to them operate as a system. Each item affects how well the other items perform their task.

The burners provided on Johnston products have been designed for a maximum efficiency on a firetube type boiler. Refinements in combustion technology and burner designs have made it more critical that everyone views the total system to ensure proper operation. This will avoid many problems that are too often considered combustion related but are really system generated, resulting from improper flue gas breeching and stack design.

Packaged firetube boilers are designed to operate at their peak performance with short, straight flue stacks. Other stack configurations can be used if they are properly engineered. Improper exhaust system designs can cause problems that come and go, or can vary with stack temperature, ambient temperature, wind conditions, operating status of other boilers connected to the exhaust system, and many other varying conditions.

A few of the problems to check in the event of an erratic operation and/or problems that appear to have no solution are:

Stack Height – The stack or chimney should be of sufficient height to extend above the roof of the building or adjoining buildings to avoid down drafts in the stack or the possibility of carrying down combustion gases to undesirable locations such as air inlet ducts or open windows in adjoining or nearby buildings.

(Source: Packaged Firetube Boiler --Engineering Manual--, American Boiler Manufacturers Association, First Edition, page 28)

A very high stack can create a high back pressure (a high positive pressure at the boiler stack connection) that the burner must overcome which may turn into a high draft (a high negative

pressure at the boiler stack connection). This can cause burner stability problems after the system has warmed to operating temperatures.

Section 3:

A very high stack that does not have some type of insulation, in addition to the problem listed above, can have widely ranging draft conditions caused by changes in the ambient air temperature. Cool ambient temperatures can chill flue gas products and reduce or eliminate draft conditions that existed with warmer ambient air. These conditions can change from winter to summer, day to night, and sometimes day to day.

Stack Exit Location – A stack exit that is located in an area where it is subject to very high and varying winds can create operational problems that appear to have no logical explanation. These problems are more difficult to find if the high and varying winds are created or amplified by the buildings located at the site.

Breeching – When required, the breeching should be as short as possible. They should be constructed of round ducts only. Round ducts are more efficient, and the large flat sides of square or rectangular ducts contribute to noise caused by resonance. The breeching must be installed with a slight upward pitch toward the stack to ensure it is self-venting.

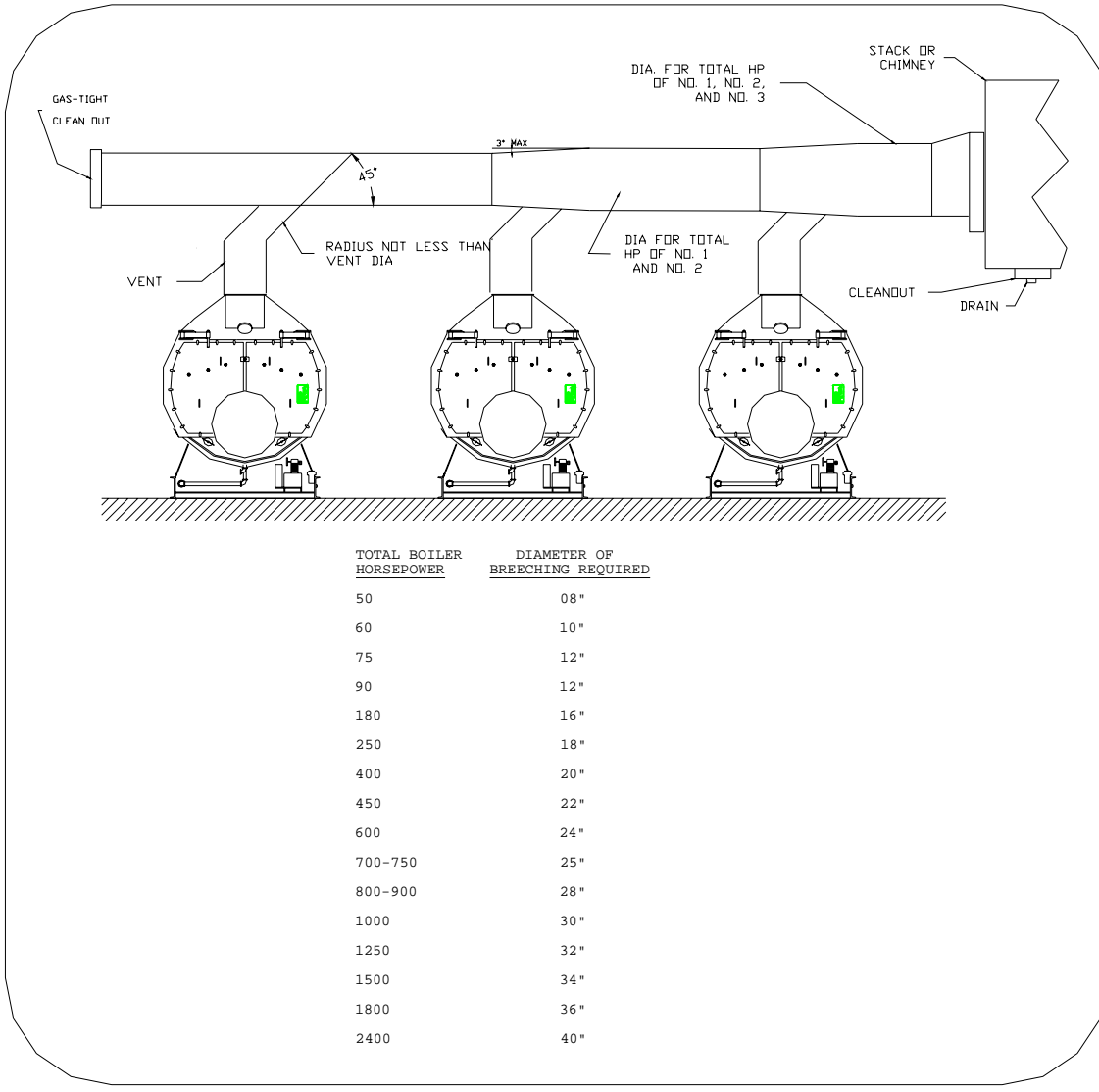
Breeching Turns – From turns as small as 30° up to 90°, the design of the turn can have a major effect on the boiler's operation. Never use an abrupt turn. "Changes in direction should be accomplished as gradually as possible. Mitered elbows should be avoided. Circular elbows should be of a minimum of four piece construction and have a minimum R/D ratio of 2.0 where R is the centerline radius of the arc and D is the diameter of the duct." (Source: Packaged Firetube Boiler –Engineering Manual—, American Boiler Manufacturers Association, First Edition, page 35)

Poorly designed turns in an exhaust system can develop reflective harmonics, or noise, that can upset or destroy stable combustion. These disturbances may not be seen at startup, but develop later as the exhaust system warms up.

Multiple Boiler Stack – A common type of installation is two or more boilers using a common exhaust system. With such a system, it is absolutely essential that the two boilers be isolated from each other. The most common method to achieve separation is the use of sequencing draft controls. Even with their installation, a detailed review of the system is required to ensure trouble-free operation.

Multiple breeching connections must never enter the stack at the same height. The flow of exhaust gases into each other can create excessive turbulence that results in combustion stability problems of flue gases being vented back into the boiler room.

Section 3:



Breeching to Stack Connections – The breeching connection to the stack should always be made with a 45° upward sweeping elbow or mitered turn. A straight in 90° connection, or bullhead type connection, is almost guaranteed to create reflective harmonics or other problems that appear to be combustion problems.

Stack Size – Pressure drops through the boiler exhaust system should be calculated and in general should not exceed 0.2" WC. Undersized stacks create excess back pressure on the boiler resulting in combustion problems, inability to make full capacity, or both.

There are several very competent manufacturers of boiler exhaust systems. They should be contacted and asked to review your exhaust system whenever there are any complications beyond a simple, short, straight stack. A little extra time and a few extra dollars will pay off in a smoother and quicker startup followed by years of successful operation.

Section 3:

E. Boiler Boil-out Procedure

It is recommended that your new Johnston Boiler be boiled-out before placing it into service. This may be done before or immediately following initial start-up. A proper boil-out will remove any grease or oil that may still be present in the waterside of the boiler as the result of boiler installation. A clean boiler waterside is one of the requirements of establishing and maintaining a stable waterside condition.

JOHNSTON BOILER COMPANY DOES NOT BOIL-OUT THE BOILER. IT IS RECOMMENDED THAT A QUALIFIED WATER TREATMENT CONSULTANT IN YOUR AREA BE CONTACTED FOR A RECOMMENDATION ON A BOIL-OUT COMPOUND, WHICH SHOULD INCLUDE ITS OWN USE PROCEDURE. IN THE ABSENCE OF A BOIL-OUT PROCEDURE, JOHNSTON BOILER RECOMMENDS THE FOLLOWING:

1. Isolate boiler from piping system (valve off).
2. Remove safety valves from the boiler. A boiler safety valve tapping on the top of the boiler pressure vessel is often used as the opening to introduce the boil-out compound into the boiler. It will also serve as a vent to fill the boiler and operate it during boil-out.

WARNING:

ONLY QUALIFIED AND EXPERIENCED PERSONNEL SHOULD PERFORM A BOILER BOIL-OUT. STEPS MUST BE TAKEN TO BE PROPERLY PROTECTED AGAINST THE HAZARDS OF HANDLING AND USING BOIL-OUT COMPOUNDS.

3. Fill the boiler with clean, ambient temperature water. Allow sufficient room for the boil-out compound solution (generally diluted) and expansion of the water. The boiler will be boiled out to atmosphere.
4. Start the boiler, following the appropriate start-up procedure included in this Manual. The boiler will be operated in the manual mode, low fire setting, for the duration of the boil-out. Observe the open safety valve tapping, as the boiler is being warmed. Due to expansion, water will have to be drained from the boiler to prevent it from overflowing. Any number of blowdown valves can be used to drain the boiler during boil-out; however, follow the boil-out compound supplier's instructions on how to dispose the chemically treated boiler water. You might not be permitted use of a normal floor drain by environmental regulations.
5. Continue to observe the open safety valve tapping on the top of the boiler. As the boiler water begins to boil, and then develop into a steady discharge of steam coming out of the open safety valve tapping, turn the boiler off. Wait until the steady stream of steam reduces to only traces of radiant steam, and then restart the boiler. Repeat this process as often as necessary for the duration of the boil-out.
6. After the boiler has been allowed to cool down to normal hot water temperatures, drain the boiler completely. Follow the boil-out compound supplier's instructions on how to dispose of the chemically treated boiler water. Refill the boiler completely with clean, hot water. Drain the boiler again.
7. Remove all handhole and manway covers from the boiler pressure vessel. Inspect the waterside of the boiler for cleanliness. Reinstall the handhole and manway covers **using new replacement gaskets.**

Section 3:

8. Reinstall the boiler safety valves on the boiler, including the discharge piping. Fill the boiler with clean, chemically treated water to its normal operating level. The boiler is now ready for initial start-up or to be placed into service.

WARNING:

HANDHOLE, MANWAY AND SMOKEBOX DOOR GASKETS MUST BE CHECKED FOR LEAKAGE FOLLOWING INITIAL OPERATION OF THE BOILER. THESE GASKETS MAY BEGIN TO LEAK DUE TO TEMPERATURE AND PRESSURE CHANGES AND EXPANSION OR CONTRACTION.

F. Recommended Water Quality For Firetube Boilers

Feed Water

pH	8.5–9.2 – Should be alkaline at all times.
Hardness	Zero ppm
Silica	Dictated by blowdown and maximum boiler residuals.
Total Dissolved Solids	T.D.S. dictated by blowdown and maximum boiler residuals.
Dissolved Oxygen	Should be reduced to less than 0.005 cc/l by mechanical deaeration and the residual controlled by addition of a suitable oxygen scavenger – normally sodium sulfite.
Suspended Matter	Zero
Oil and Grease	Zero

Boiler Water

pH	10.5-11.5
Alkalinity (m)	700 ppm (max.)
T.D.S.	Boilers sized 20,000 pph or less – 3500 ppm (max.). Boiler sized larger than 20,000 pph – 2500 ppm (max.)
Phosphate Residual	50 ppm as PO ₄ (min.)
Dissolved Oxygen	Zero If sodium sulfite is used for oxygen scavenging, maintain 25-50 ppm as Na ₂ SO ₃ .
Suspended Matter	50 ppm (max.)
Silica	125 ppm (max.)

This information is supplied as general guidance only and does not absolve the boiler owner from the responsibility of determining and maintaining water standards appropriate to the specific local water chemistry and specific boiler use.

Section 4: Maintenance

A. General

A good maintenance program is essential to the lasting operation of your Johnston Boiler. Properly maintaining the boiler will reduce unnecessary downtime, lower repair costs, and increase safety.

All electronic and mechanical systems require periodic maintenance. Automatic features do not relieve the operator from maintenance duties.

A chart of added energy costs due to scale deposits can be found in Section 5 item "D" of this manual.

B. Part-Specific Maintenance

Most of the components and systems of your Johnston Boiler require little maintenance other than regular inspection. Cleanliness is essential to the inspection of the boiler. Keep the exterior free of dust. Keep the controls clean.

See individual component manuals for more information on specific component maintenance issues.

C. Maintenance Schedule

Johnston Boiler Company recommends the following maintenance schedule for the upkeep of your Johnston Boiler. Any omission from this schedule could cause the Warranty to be voided. Only qualified and experienced boiler, burner, and control personnel should attempt any maintenance and/or repair on any boiler/burner. Be sure you have read and understand this entire manual before attempting maintenance or repair.

Daily:

The following maintenance tasks should be performed daily by the operator:

1. Check the boiler for a proper water level. Low water can lead to over heating of the boiler heating surfaces. High water can lead to carryover on steam boilers. Both conditions are dangerous.
2. Test the water cut-off controls. Also refer to item 7.
3. Check the operation of the boiler feedwater pump, control, and valve (regulator).
4. Check the boiler feedwater pump for proper operating pressures and temperatures.
5. Check over the boiler for proper operating pressures and temperatures.
6. Check to make sure that an adequate air supply into the boiler room is being maintained.
7. Blowdown the boiler. The water column and gauge glass (steam boilers only) and low water cut-off control(s) drain valves must be operated daily. A 15 second blowdown is adequate. The boiler bottom blowdown valves should be operated daily. First open the quick opening valve (closest to the boiler). Then open and close the slow opening valve. The length of time it takes to do so represents the normal length of time for a boiler blowdown. Now close the quick opening valve. Crack open and close the slow opening valve. This will relieve any pressure trapped between the valves.
8. Check for leaks. Any leaks in the piping, fittings, controls, handhole, or manway openings should be attended to promptly. All pressures and temperatures should be taken off the boiler and the boiler drained down, isolated and locked out before any attempt to repair a waterside leak is made. When replacing a gasket, sealing surfaces must be properly cleaned and prepared.
9. Check the condition of the boiler water for proper chemical treatment.
10. Maintain a clean, orderly, and safe boiler room.

Weekly:

The following maintenance tasks should be performed weekly by the operator:

1. If installed, check the boiler outlet flue gas damper for proper and smooth operation. Check the linkage joints, arms, and rods for tightness.
2. Check the peepsite and sight port(s) for cracks in the lenses.

Section 4:

Monthly:

The following maintenance tasks should be performed monthly by the operator:

1. Check operation of the surface or continuous blowoff valve.

Annually:

The following maintenance tasks should be performed annually by the operator:

1. Check gauges and thermometers for proper calibration.
2. Open, clean (flush) and inspect the boiler waterside, including all water level controls, piping and fittings.
3. Open, clean and inspect the boiler fireside. Inspect the condition of the boiler insulation, including any refractory if present. Patch, replace or repair as necessary.
4. Check the condition of the fireside gasketing. Check for hardness and/or cracking. Replace fireside gasketing as needed, but not less than every three years.
5. Replace waterside gasketing no less than once a year. Handhole and manway gaskets may be required to be replaced more frequently. Handhole and Manhole gaskets should be checked for condition (outside appearance) quarterly.
7. Lubricate studs and nuts and fluebox door hinges.

D. Idle Boiler Lay-Up

1. General

When a boiler is to be off-line or idle for any extended period of time, it must be laid-up. There are a number of methods that can be used to lay-up an idle boiler. Either of the following can be used to lay up a Johnston Boiler. If your boiler is not a Johnston Boiler, follow the manufacturer's instructions for laying-up your boiler.

2. Wet Method

When a boiler may be laid-up for only a brief period of time (not necessarily known), it can be laid up using the wet method. This is usually used when a boiler may be needed back in service on short notice.

The operating boiler should be blown down as would normally be done, just prior to lay-up. The boiler must then be shut down, secured (valved-off), and cooled. Once the boiler is cool, it must be vented and drained. The boiler should then be refilled with clean water and drained again for flushing purposes.

The boiler must then be completely filled (flooded) with clean and chemically treated water. An oxygen scavenger should be used to prevent pitting and corrosion. Seal off (close) the vent of the completely filled boiler. The boiler must be kept completely filled during the lay-up period. Also keep the boiler secured (valved off) for the entire lay-up period.

When the boiler is needed to be placed back into service, simply lower its water level to the normal operating level and begin operation of the boiler (vent the boiler while lowering the water level).

3. Dry Method

When it is known that the boiler will be laid up for an extended period of time, the dry method is used. It is also used when an idle boiler filled with water is exposed to the possibility of freezing temperatures.

Section 4:

The operating boiler should be blown down, as would normally be done, just prior to lay-up. The boiler must then be shut down, secured (valved off) and cooled. Once the boiler is cool, it must be vented and completely drained. All handhole and manway covers must be removed. The waterside of the boiler should then be flushed completely clean. Power washing is recommended. The waterside of the boiler should then be allowed to completely dry.

Utilizing the handhole and manway access openings, using desiccant (or equal) in cloth bags, with retrieving lines attached to the bags, place a sufficient number of the bags throughout the boiler pressure vessel. Sixteen pounds of desiccant is required for every thousand gallons of boiler water capacity (flooded). Leave the retrieving lines that are attached to the bags in the area of the handhole and manway openings. Reinstall all handhole and manway covers. The old gaskets may be reused if in good condition. Close the boiler vent. No greater than a 50% humidity level is to be maintained in the waterside of the boiler, during that period the boiler will be laid-up.

When the boiler is required to be placed back in service, all desiccants must be removed from the boiler waterside. New replacement handhole and manway gaskets must also be installed. The boiler must then be filled with clean and chemically treated boiler water.

Depending on duration of lay-up, one might consider applying desiccant to the fireside as well. Apply 1.2 oz/cu ft. of space.

Section 5: Engineering

A. Glossary of Terms

<u>Absolute Pressure</u>	The sum of gauge pressure and atmospheric pressure.	<u>Boiler Horsepower</u>	The evaporation of 34.5 pounds of water per hour from and at a feedwater temperature of 212°F.
<u>Accumulation Test</u>	Test used to establish the relieving capacity of boiler safety relief valves	<u>Boiler Lay-Up</u>	Removing a boiler from service for a period of time. A boiler can be preserved wet or dry.
<u>Acid Dew Point</u>	Temperature at which acids begin to settle out of flue gases.	<u>Boiler Room Log</u>	A data sheet to record pressures, temperatures of other operating conditions of a boiler on a continuous basis.
<u>Alkalinity</u>	Determined by boiler water analysis. Boiler water with a pH over 7 is considered alkaline.	<u>Boiler Shutdown</u>	A sequence of operation completed when taking a boiler off line.
<u>Ambient Temperature</u>	Temperature of the surrounding area.	<u>Boiler Startup</u>	A sequence of operations completed when preparing a boiler for service.
<u>Ampere</u>	Unit of measure of electrical current.	<u>Boiler Vent</u>	Port coming off highest part of the waterside of the boiler that is used to vent air from the boiler when it is filled. Also used to prevent a vacuum from forming when the boiler is drained.
<u>Anion</u>	Ion that has a negative electrical charge.	<u>Boiling Point</u>	Temperature at which water changes into steam.
<u>Area</u>	The number of unit squares equal to the surface of an object.	<u>Bottom Blowdown</u>	Periodic draining of part of the water in the boiler to remove the heavy sludge that settles to the bottom of a vessel.
<u>ASME Code</u>	Code written by the American Society of Mechanical Engineers that controls the construction, repairs and operation of boilers and their related equipment.	<u>Breeching</u>	Ducting from boiler flue gas outlet to stack (or chimney).
<u>Atmospheric Pressure</u>	Pressure at sea level (14.7 PSI).	<u>British Thermal Unit</u>	(BTU) Amount of heat necessary to raise the temperature of 1 lb. of water 1°F.
<u>Atomization</u>	Process of breaking a liquid fuel stream into a mist of tiny droplets.	<u>By-Pass Line</u>	A pipeline that passes around a control.
<u>Atomize</u>	To break up fluids into a fine mist.		
<u>Boiler</u>	Closed vessel in which water under pressure is elevated in temperature by application of heat.		
<u>Boiler Capacity</u>	Pounds of steam or BTU's of hot water a boiler is capable of producing.		

<u>Calibrate</u>	Adjusting a gauge, control or piece of equipment to conform to a test gauge, control or piece of equipment.	<u>Continuous Blowdown</u>	Small stream of water that constantly drains from a boiler to control the quantities of impurities in a boiler on a continuous basis.
<u>Carryover</u>	Particles of water that flow with steam into the system piping.	<u>Convection</u>	A method of heat transfer that occurs as heat moves through a fluid.
<u>Cavitation</u>	Condition caused when a portion of water or other liquid entering the eye of a pump impeller flashes into steam or vapor bubbles. Causes pitting of pump impellers.	<u>“Cracking” Open</u>	Slowly opening a valve, generally to allow equalization.
<u>Celsius (Centigrade)</u>	Temperature scale commonly used with the metric system of measurements. The freezing point of water on this scale is 0° and the boiling point of water is 100° at normal atmospheric pressure.	<u>Cross “T”</u>	Used in water column piping for inspection for being clean and clear.
<u>Centrifugal Force</u>	Force caused by a rotating impeller that builds up in a centrifugal pump.	<u>Cut-In Pressure</u>	Automatic pressure control setting at which the boiler turns on.
<u>Check Valve</u>	One-way flow valve for fluids.	<u>Cut-Out Pressure</u>	Automatic pressure control setting at which the boiler turns off.
<u>Combustible Material</u>	Any material that burns when it is exposed to oxygen and heat.	<u>Cycle of Concentration</u>	Number of times solids in a particular volume of water are concentrated as compared to concentration of the solids in the original volume of water.
<u>Combustion</u>	The rapid union of oxygen with an element or compound that results in the release of heat.	<u>Deaerator</u>	Pressure vessel that removes oxygen from the feedwater before going into the boiler.
<u>Complete Combustion</u>	The burning of all the supplied fuel using the minimum amount of excess air.	<u>Dealkalizer</u>	Ion - Exchange unit that works exactly like a sodium zeolite water softener, but removes anions and replaces them with chloride.
<u>Compound Gauge</u>	Combination pressure gauge and vacuum gauge.	<u>Differential Pressure</u>	Difference between two pressures at different points.
<u>Condensate</u>	Steam that has lost its heat and returned to water.	<u>Differential Setting</u>	Difference between the pressure or temperature at which the automatic control turns the burner on, and the pressure or temperature at which the automatic control turns the burner off.
<u>Condense</u>	Process whereby steam turns back to water after the removal of heat.	<u>Dissolved Solids</u>	Impurities that have passed into solution.
<u>Conduction</u>	A method of heat transfer in which heat moves from molecule to molecule.	<u>Draft</u>	The difference in pressures between two points that cause air or gases to flow.

<u>Economizer</u>	A tubed chamber that uses the gases of combustion to heat boiler feedwater.	<u>Flash Steam</u>	Created when water at a high temperature has a sudden drop in pressure.
<u>Element</u>	A basic substance consisting of atoms of the same type.	<u>Foaming</u>	Rapid fluctuations of the boiler water level that can lead to priming or carryover. Caused by impurities on the surface of the boiler water.
<u>Enthalpy</u>	Total heat in steam.	<u>Foot Pound</u>	Unit of measure that equals the movement of an object by a constant force (in pounds) to a specific distance (in feet).
<u>Erosion</u>	Wearing away of matter.	<u>Force</u>	Energy exerted or brought to bear on.
<u>Excess Air</u>	Air more than the theoretical amount needed for combustion.	<u>Forced Draft</u>	Mechanical draft produced by a fan
<u>Factor of Evaporation</u>	Heat added to water in an actual boiler in BTU per pound and divided by 970.3.	<u>Furnace Volume</u>	Amount of space available in a boiler furnace to complete combustion.
<u>Fahrenheit</u>	Temperature scale commonly used with the U.S. system of measurements. The freezing point of water on this scale is 32° and the boiling point of water is 212° at normal atmospheric pressure.	<u>Gate Valve</u>	Valve used to shutoff or admit flow.
<u>Feedwater</u>	Water that is supplied to a boiler.	<u>Gauge Glass</u>	Glass connected to a water column or directly to a boiler that allows an operator to see the water level inside a boiler.
<u>Feedwater Treatment</u>	Using softwater and chemicals in the boiler feedwater. Protects against scale and corrosion.	<u>Gauge Pressure</u>	Pressure above atmospheric pressure. Assumes atmospheric pressure being zero.
<u>Fire Point</u>	Temperature at which fuel oil burns continuously when exposed to an open flame.	<u>Gas Analyzer</u>	Used to analyze the gases of combustion to determine combustion efficiency.
<u>Firetube Boiler</u>	Has heat and gases of combustion passing through the furnace and boiler tubes surrounded by water.	<u>Gas Leak Detector</u>	A device to locate gas leaks in the boiler room.
<u>Firing Rate</u>	Amount of fuel the burner is capable of burning in a given unit of time.	<u>Gases of Combustion</u>	Gases produced by the combustion process.
<u>Flame Failure</u>	When the burner pilot or main flame goes out on its own.	<u>Globe Valve</u>	Valve used to throttle or shutoff flow.
<u>Flame Scanner</u>	Electronic device that confirms that the pilot and main burner flame exist.	<u>Gravity</u>	Natural force that makes objects on earth fall to the lowest point possible.
<u>Flash Point</u>	Temperature at which fuel oil, when heated produces a vapor that flashes when exposed to an open flame.		

<u>Handhole</u>	Small access hole, smaller than a manhole (manway), used for looking and reaching into the boiler shell during inspections.	<u>Low Pressure Boiler</u>	A boiler that operates at a steam pressure of not more than 15 PSIG.
<u>Header</u>	Manifold that feeds several branch pipes or takes in steam or water from several smaller pipes.	<u>Low Water</u>	Lower than acceptable water level in a boiler.
<u>Heat Exchanger</u>	Any piece of equipment where heat is transferred from one substance to another.	<u>Low Water Fuel Cutoff</u>	Device located slightly below the acceptable level of a boiler. Shuts off the boiler burner in the event of low water conditions.
<u>Heating Surface</u>	Any part of a boiler metal that has hot gases on one side and water on the other.	<u>Main Steam Stop Valve</u>	Gate valve in the main steam line between the boiler and the steam header.
<u>Heat Recovery System</u>	Equipment that is used to reclaim heat that is normally lost.	<u>Makeup Water</u>	Water that must be added to the boiler to make up for condensate that was dumped, lost through boiler blowdowns or leaks in the system.
<u>Heat Transfer</u>	Movement of heat from one substance to another that can be accomplished by radiation conduction or convection.	<u>Manhole (Manway)</u>	Hole on the steam and waterside of a boiler used to clean, inspect and repair a boiler.
<u>Heating Value</u>	Expressed in BTU's. Heating value of fuel varies with the type.	<u>Maximum Allowable Working Pressure</u>	(MAWP) – Highest legal pressure at which a pressure vessel may be operated.
<u>High Pressure Boiler</u>	A boiler that operates over a steam pressure of 15 PSIG.	<u>MOD Motor</u>	Motor that controls the firing rate and airflow for burners. Single point positioning systems have only one MOD motor, which uses linkages to connect to all functions. Parallel point positioning systems have separate motors for each function. (Typically referred to as "servo" motors)
<u>Hot Water Boiler</u>	Boiler that is completely full of water that produces only hot water, not steam.	<u>Modulating Pressure Control</u>	Control device that regulates the burner for a higher or lower fuel-burning rate depending on steam pressure in the boiler.
<u>Hydrostatic Pressure</u>	Water pressure per vertical foot (.433) exerted at the base of a column of water.	<u>Multiple-Pass Boiler</u>	Boilers that are equipped with a means to direct the flow of the gases of combustion so that the gases make more than one pass over the heating surfaces.
<u>Inches of Mercury</u>	(IN.Hg) - Unit of measure for vacuum.		
<u>Incomplete Combustion</u>	Occurs when all the fuel is not burned, resulting in the formation of smoke, soot or CO.		
<u>Infrared</u>	Invisible light rays produced by the combustion process and detected by a flame scanner.		
<u>Latent Heat</u>	Heat added above boiling point.		
<u>Laying Up</u>	Taking a boiler out of service for longer than a normal period of time.		

<u>Natural Draft</u>	Caused by the difference in weight between a column of hot gases of combustion inside the chimney (stack) and a column of cold air of the same height outside the chimney.	<u>Pneumatic System</u>	A system of control that uses air as the operating medium.
<u>Non-Condensable Gas</u>	Any gas that will not change into a liquid when its temperature is reduced.	<u>Pounds of Steam per hour</u>	(LB/HR) - Unit of measure that expresses the amount of steam produced by a boiler in one hour.
<u>Non-Return Valve</u>	Combination shutoff and check valve that allows steam to pass out of the boiler, but a back flow of steam from a drop in pressure causes the valve to close.	<u>Popping Pressure</u>	Predetermined pressure at which a safety relief valve opens and remains open until the pressure drops.
<u>Normal Operating Water Level</u>	(NOWL) - Level of the boiler water at normal operation.	<u>Post-Purge</u>	The passing of air through the boiler fireside after normal burner shutdown.
<u>Overfiring</u>	Forcing a boiler beyond its designed steam producing capacity.	<u>Pour Point</u>	The lowest temperature at which a fuel oil flows as a liquid.
<u>Package Boiler</u>	Boiler that comes completely factory assembled, with exception of those items that have to be removed from the boiler for shipment.	<u>Pre-Purge</u>	The passing of air through the boiler fireside prior to pilot and main burner flame lightoff.
<u>Parallel Positioning Control System</u>	A programmer controlled system of controlling the inlet air damper, FGR damper, and fuel valves of the burner. Separate servo motors are used for each component controlled.	<u>Pressure</u>	Application of force commonly measured in PSIG.
<u>Passes</u>	Number of times gases or combustion flow the length of the pressure vessel as they transfer heat to the water.	<u>Pressure Reducing Station</u>	Where higher pressure steam is reduced in pressure for lower pressure needs.
<u>Perfect Combustion</u>	Burning of all the fuel with the theoretical amount of air.	<u>Primary Air</u>	Forced air supplied to the burner..
<u>PH</u>	Value representing how acidic or alkaline water is.	<u>Priming</u>	Severe form of carryover in which large slugs of water leave the boiler with the steam.
<u>Phosphates</u>	Chemicals that cause hardness particles to settle out as a heavy sludge.	<u>Process Steam</u>	Steam used in a plant for manufacturing or processing purposes.
<u>Power</u>	Unit of measure that equals the amount of foot pounds of work in a given period of time.	<u>Products of Combustion</u>	Gases that are formed as fuel is burned.
		<u>Programmer</u>	Device that controls the burner sequence of operation.
		<u>Proving Pilot</u>	Sighting the pilot through a flame scanner to verify that the pilot is lit.
		<u>Pounds Per Square Inch</u>	(PSI) Number of pounds of pressure exerted on one square inch of a given area.
		<u>Purge Period</u>	Time allotted for blower to operate without fuel or ignition.

<u>Quality of Steam</u>	Term used to express the moisture content present in saturated steam. Quality of steam affects the BTU content of the steam.	<u>Smoke Density</u>	Varies from clear to dark. Determined by the amount of light that passes through the smoke as it leaves the boiler.
<u>Rate of Combustion</u>	The amount of fuel that is being burned in the furnace per unit of time.	<u>Sodium Zeolite Water Softener</u>	Ion - Exchange water softener that uses a bronze solution and resin beads to soften water.
<u>Raw Water</u>	Untreated water.	<u>Solid State</u>	An electronic system using transistors in place of electronic tubes.
<u>Reseat Pressure</u>	The pressure at which a safety valve will reseat after lifting.	<u>Soot</u>	Fine powder consisting primarily of carbon that results from incomplete combustion.
<u>Ringlemann Chart</u>	Chart used as a measure of determining smoke density.	<u>Spalling</u>	Hairline cracks in boiler refractory due to changes in fireside temperatures.
<u>Safety Valve</u>	Valve that keeps the boiler from exceeding its maximum allowable working pressure.	<u>Specific Gravity</u>	Weight of a given volume of a material divided by the weight of an equal volume of water measured at 60°F.
<u>Safety Valve Capacity</u>	Volume to discharge.	<u>Spontaneous Combustion</u>	Occurs when combustible materials self-ignite.
<u>Sample Cooler</u>	Closed heat exchanger that cools a sample of boiler water to be tested.	<u>Stack</u>	Outlet to the atmosphere for the gases of combustion. Used to create a draft.
<u>Saturated Steam</u>	Steam at a temperature that corresponds with its pressure.	<u>Static Head Pressure</u>	(SHP) - Pressure at the bottom, or at some specified point, of a column of still liquid.
<u>Scale</u>	Deposits in the boiler waterside caused by improper boiler water treatment.	<u>Steam</u>	Gaseous form of water. Steam is odorless, colorless and tasteless.
<u>Scotch Marine Boiler</u>	A firetube boiler with an internal furnace.	<u>Steam Boiler</u>	A closed pressure vessel in which water is converted to steam by the application of heat.
<u>Secondary Air</u>	Air that is needed to complete the combustion process.	<u>Steambound</u>	Condition occurring when the temperature in the open feedwater heater gets too high and the feedwater pump cannot deliver water to the boiler.
<u>Sediment</u>	Particles of foreign matter present in the boiler water.	<u>Steam Space</u>	The space above the water line in a steam boiler.
<u>Sensible Heat</u>	Heat that can be measured by a change in temperature.	<u>Steam Trap</u>	Mechanical device used to remove condensate from steam piping.
<u>Single Point Position System</u>	Control system in which only one control motor is used to operate a system of linkages connected to controls.		
<u>Sludge</u>	Accumulated residue produced from impurities in water.		

<u>Sulfur</u>	A combustion element found in coal and fuel oil.	<u>Vertical Firetube Boiler</u>	Boiler that has firetubes in a vertical position.
<u>Superheated Steam</u>	Steam at a temperature above its corresponding pressure.	<u>Viscosity</u>	Ability of a liquid or semi-liquid to resist flow.
<u>Surface Tension</u>	Caused by impurities on the top of the water in a steam boiler.	<u>Waste Heat Recovery Boiler</u>	Boiler in which heat that would otherwise be discarded is used in lieu of fuel fired burner.
<u>Tensile Stress</u>	Occurs when two forces of equal intensity act on an object, pulling in opposite directions. Affects boiler plates and staybolts.	<u>Water Column</u>	Metal vessel installed on the outside of a boiler shell or drum at the NOWL that helps an operator determine the water level in a boiler.
<u>Therm</u>	100,000 BTU	<u>Water Hammer</u>	A violent reaction caused when steam and water collide in a steam line.
<u>Thermal Efficiency</u>	The ratio of heat that is absorbed by the boiler to the heat available in the fuel per unit of time.	<u>Wet-Lay-Up</u>	Method of short term boiler storage that keeps the boiler free from oxygen on the inside, which prevents damage from corrosion.
<u>Thermal Shock</u>	Stress imposed on pipe or vessel by a sudden and drastic change in temperature.	<u>Working Pressure</u>	The pressure at which the boiler is operated.
<u>Total Force</u>	Total pressure that is acting on an area, determined by diameter and pressure.		
<u>Total Heat</u>	Sum of sensible heat and latent heat.		
<u>Turbulence</u>	Erratic movement of water in the boiler.		
<u>Ultraviolet</u>	A form of light that is produced during combustion. Seen by flame scanner.		
<u>Vacuum</u>	A pressure below atmospheric pressure.		
<u>Vacuum Breaker</u>	Vent above the liquid that allows air to be pulled into the tank to prevent formation of a vacuum.		
<u>Vacuum Gauge</u>	Gauge used to measure pressures below atmospheric pressure.		
<u>Valve</u>	Mechanical device that starts, stops or regulates flow of a liquid, gas or loose bulk material.		
<u>Vapor</u>	Diffused matter in a gaseous state.		

Section 5: B. Boiler Formulas

Boiler Horse Power (HP):

$BHP = (Lb/hr) * FE / 34.5$
where Lb/hr is pounds of steam per hour and FE is the factor of evaporation.

Cycle of Concentration of Boiler Water:

$CYC = Bch / FCh$
where Bch is ppm water chlorides and FCh is ppm feedwater chlorides.

Differential Setting (lb):

$\Delta S = P1 - P2$
where P1 is the cutout pressure and P2 is the cut in pressure

Factor of Evaporation:

$FE = SH + LH / 970.3$
where SH is the sensible heat and LH is the latent heat.

Force (lb):

$F = P / A$
where P is pressure (psi) and A is area (in²).

Horsepower (HP):

$HP = (d * t) / (t * 33000)$
where d is distance, F is force, and t is time.

Inches of Mercury (in):

$InHG = P / 0.491$
where P is pressure

Percent of Blowdown:

$\%BD = (PP - RP) / PP$
where PR is popping pressure and RP is reseal pressure

Rate of Combustion (Btu/hr)

$RC = H / (Vf * t)$
where H is heat released (BTU), Vf is volume of furnace (ft³), and t is time (hr).

Return Condensate Percentage in Feedwater

$RC\% = (MC - FC) / (MC - CC)$
where MC is the makeup conductivity (μohms), FC is the feedwater conductivity (μohms), and CC is the condensate conductivity (μohms).

Static Head Pressure (lb):

$SHP = Bpr * 2.31$, Where Bpr=Boiler Pressure (psi)

Steam:

$S = HP * 34.5 * t$
where HP is boiler horsepower and t is time (h).

Temperature Conversions:

F to C
 $C = (F - 32) / 1.8$

C to F
 $F = (1.8 * C) + 32$

Total Force (lb)

$TF = P * A$
where P is pressure (psi) and A is the area of valve disc exposed to steam (sq. in.)

Water Column (in)

$WC = P / 0.03061$
where P is pressure (psi).

C. Combustion

Flue gas analysis:

Boiler flue gas analysis is used to determine combustion efficiency.	
Carbon Dioxide (CO ₂)	Indicates complete combustion
Carbon Monoxide (CO)	Indicates incomplete combustion
Oxygen (O ₂)	Indicates the presence of excess air
Oxides of Nitrogen (NO _x)	A product of high temperature combustion
Combustibles	Material that burns when exposed to oxygen and heat

It is typical to target oxygen levels of 8% in low fire and 3% in high fire for gas fired burners.

It is typical to target oxygen levels of 6% in low fire and 4% in high fire for oil fired burners.

Johnston Boiler Company recommends no greater level than 200 ppm of Carbon Monoxide in a burner operation.

Johnston Boiler Company recommends zero combustibles for a gas fired burner.

Section 5:

Johnston Boiler Company recommends a maximum #2 Smokespot (Ringelmann Chart) in its oil fired burner.

Air Properties:

For a burner originally adjusted to 15% air, changes in combustion air temperature and barometric pressure cause the following in excess air:

Air Temperature	Barometric Pressure (In. HG)	Resulting Excess Air %*
40	29	25.5
60	29	20.2
80	29	15.0
100	29	9.6
120	29	1.1
80	27	7.0
80	28	11.0
80	29	15.0
80	30	19.0
40	31	34.5
60	30	25.0
80	29	15.0
100	28	5.0
120	27	-5.5

* Expressed as a percent of the Stoichiometric air required.

D. Energy Loss from Scale Deposits

ENERGY LOSS FROM SCALE DEPOSITS IN BOILERS	
SCALE THICKNESS (INCHES)	EXTRA FUEL COST (PERCENT)
1/32	8.50
1/25	9.30
1/20	11.10
1/16	12.40
1/8	25.00
1/4	40.00
3/8	55.00
1/2	70.00