Sellers® S-Series Modulating Digital-Control Immersion-Fired Steam Boilers

INSTALLATION & OPERATING INSTRUCTIONS

The innovative *Sellers*® immersion-fired boilers are durable, reliable, proven.

- Low maintenance
- No thermal shock
- 20-minute steam
- Longest warranty

Note: Place a copy of these instructions next to the boiler/heater; notify the owner to keep it for future reference.

If shipping damage is noted, the receiver must make a damage claim to recover damage.

WARNING: If these instructions are not followed exactly, a fire or explosion may result causing property damage, personal injury, or death.

FOR YOUR SAFETY: Do not store or use gasoline or other flammable vapors and liquids or other combustible materials in the vicinity of this or any other appliance. Doing so may result in an explosion or fire.

WHAT TO DO IF YOU SMELL GAS:

- Do not try to light any appliance.
- Activate the emergency stop pushbutton and exit the boiler room.
- Immediately call emergency services from a safe location.

Installation must be performed by a qualified installer and startup must be performed by a qualified service technician.

Sellers® MANUFACTURING CO.

918 West Walnut St. Danville, Kentucky 40422
Visit us on the Web: **www.sellersmfg.com**
For customer service: info@sellersmfg.com or call 859-236-3181.

Industrial boiler equipment design and manufacturing excellence for over 80 years.
Proudly made in Danville, Kentucky, USA.

SAFETY

Safety messages and instructions located in this manual and on the boiler provide warnings to you and others of potential hazards. Before installing, operating, or servicing this boiler, it is important to read and understand these safety instructions and messages.

DANGER indicates the presence of immediate hazards which, if not avoided, could result in severe personal injury, death, or substantial property damage.

WARNING indicates a potentially hazardous situation which, if not avoided, could result in severe personal injury, death, or substantial property damage.

CAUTION indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury, or property damage.

Qualified Installer: Must have the ability of a licensed tradesman in the fields of gas supply, plumbing and venting, including a thorough understanding of the National Fuel Gas Code as it relates to gas-fired boilers. The installer must thoroughly review and understand this manual.

Service Technician: An individual trained and experienced in boiler startups and trained in Sellers's boiler startups. Individuals must also have training and experience in the controls used, steam and feedwater systems, and related utilities.

Verify that the gas hooked up to the boiler is the same type specified on the nameplate label, located on the boiler.

Should overheating occur, or if the gas valve fails to shut, do not turn off the electrical supply to the boiler. Shut off the gas supply at a location away from the boiler.

Do not use this boiler if any part has been underwater. Have the boiler inspected by a qualified Service Technician. Replace any electrical or gas control system which has been underwater.

Maintain the area surrounding the boiler, keeping it clean and free of combustible materials, gasoline, and other flammable liquids or vapors. The boiler should never be covered.
This boiler requires a constant supply of fresh air for proper combustion. Failure to provide an adequate flow of fresh air may result in serious injury or death.

Sellers S-Series Immersion Fired Boiler Pre-Startup Check List

S.O. Number: _____ Model Number: _____
Job Name: _____ Location: _____
Representative: _____ Purchaser: _____

Mark the following once they have been completed and checked to be in accordance with quote:

Service Room Around Boiler: _____ Pilot Gas Connection: _____
Front Burner Swing: _____ Main Gas Connection: _____
Tube Pull Clearance: _____ Gas Train Venting: _____
Housekeeping Pad or Piers: _____ Gas Cleanout Leg: _____
Combustion Air Supply: _____ Gas Supply Pressure: _____
Feedwater Connection: _____ Electrical Connection: _____
Steam Connection: _____ Wiring Alteration? _____
Bottom Blowoff Connection: _____ Supply Voltage: _____
Water Column Blowoff Connection: _____ Control Circuit Voltage: _____
Surface Blowdown Connection: _____ Blower Rotation Correct: _____
Safety Relief Valve Piping: _____ Boilout/Cleanout Completed? _____
Stack Installation and Proper Draft: _____ Record Draft (Manometer) Reading: _____
Check Front Door Gasket Seal: _____ Check Spark Rod Gap: _____
Check Pilot Flame Rod Position: _____ Check Main Flame Rod Position: _____

Additional Notes:

_____

_____

_____

_____

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_____

_____

Performed By: _____ Date: _____

MUST BE RETURNED TO INFO@SELLERSMFG.COM
FOR WARRANTY VALIDATION

Document # D-755

Sellers S-Series Immersion Fired Boiler Startup Report

S.O. Number: _____ Model Number: _____

Job Name: _____ Location: _____

Purchaser: _____ Representative: _____

Mark the following controls once checked:

Primary LWCO: _____ Conbustion Air Proving Switch: _____

Aux. LWCO: _____ Operating Pressure Sensor: _____

High Gas Pressure Switch: _____ High Pressure Limit: _____

Low Gas Pressure Switch: _____

Gas Pressures

Gas Pressure to Gas Train: _____ Regulated Gas Pressure: _____

Regulated Pressure to Pilot: _____

Combustion Settings

	Low									High
Firing Rate										
% O_2										
% CO_2										
Co pm										
NO_x										
Air Temp										
Gross Stack Temp										
Draft (at stack)										
Steam Press.										
Damper Degree										
Fuel Degree										
2nd Valve Degree										
Flame Signal										

High Fire Motor Amps and Volts L1: _____ L2: _____ L3: _____

Performed By: _____ Date: _____

Company: _____ Phone Number: _____

Notes:

MUST BE RETURNED TO INFO@SELLERSMFG.COM FOR WARRANTY VALIDATION

Document # D-756

Table of Contents

1. GENERAL INFORMATION

This manual covers the S-Series packaged immersion-fired fire-tube boiler manufactured by Sellers Manufacturing Co. These boilers are intended to be used in commercial and industrial applications that require steam for heating or process applications. The boiler is assembled with an integral burner and includes many of the basic controls and fuel trains, but many other components and utilities are required to make the unit operational. The field installation would typically include stacks and breeches; fuel, electrical, and water supply; and steam lines, all installed in a properly designed boiler or mechanical room. The proper design and installation of these systems is the responsibility of the owner.

This manual is supplied to the boiler owner and operator with information regarding installation, startup, operation, and maintenance. It is the ultimate responsibility of the boiler owner to operate and maintain this equipment in a safe manner.

The S-Series boiler is a "packaged boiler", which means that it has an integral burner and includes all the burner controls, gas trains, and water controls, but not all the auxiliary systems required for operation. Typically, it is used as part of a much larger boiler room system that would include pumps, piping, controls, and stack; designed as an integral system, engineered by an experienced boiler room engineer, and installed and maintained by an experienced boiler room mechanical contractor.

The vessel is a single-pass design where individual burners are fired into each of the boiler tubes. The burner incorporates a fuel-air pre-mix that is channeled to the individual firing nozzles located in front of each tube. Because this vessel is a single-pass design, there are no turnaround chambers with the related refractory or additional pressure vessel components.

This manual is intended to cover the vessel and burner, focused on those components manufactured by Sellers Manufacturing Co. There are many other significant components that are made by other vendors, and their component manuals are included with this product. The details of their operation are not covered within this manual. A wiring diagram and parts list are also provided, which identify the specifics of this unit.

⚠WARNING

DO NOT ATTEMPT TO START, ADJUST OR MAINTAIN THIS BURNER WITHOUT PROPER TRAINING OR EXPERIENCE. FAILURE TO USE KNOWLEDGEABLE TECHNICIANS CAN RESULT IN EQUIPMENT DAMAGE, INJURY OR DEATH.

While the information in this manual is deemed to be correct at the time of printing, Sellers Manufacturing Co. retains the right to make product improvements which may not be represented in this manual. Any product changes on the unit will be reflected in the bills of material and wiring diagrams. If there are any questions concerning this manual, or its representation of the product, please feel free to contact Sellers at 859-236-3181.

1.1. Product Offering

The S-Series boiler is designed for either low pressure steam (ASME Section IV, 15 PSI and under) and high-pressure steam (ASME Section I, over 15 PSI). The sizes range from 40 to 900 boiler horsepower. The standard fuel is natural gas, but the unit can also be designed to handle LP or biogas. The unit includes an integral burner, controls, fuel train and other components to provide a complete packaged boiler.

The burner can also be operated as a low emission product when adjusted accordingly and can provide low NOx emissions under 30 ppm. These lower emission rates can impact the ratings and should be coordinated with the sale of the unit to verify performance. There will be a reduction in capacity when operating at 30 ppm NOx. The turndown rates for this product vary with size, fuel, options and fuel trains, but can be up to 5:1 turndown. All burners are capable of at least 3:1 turndown.

Numerous options are available for the S-Series boiler, including the controls, fuel trains, and trim. The boiler can also be engineered and manufactured to meet numerous specifications and/or regulations.

Fire-tube boilers are rated based on the energy output of the steam, with each boiler HP equal to 33,475 Btu/hr. For simplicity, an assumed efficiency of 80% is used to provide both the energy input and output, as shown in Table 1.1. With higher efficiency, the input is reduced. The actual efficiency will vary with the operating pressure and/or temperatures of the boiler, and makeup of the fuel and air, so that the input can vary.

Boiler Horse Power	Estimated Heat Input (MBH) Based on 80% Efficiency	Rated Output (MBH)
40	1,674	1,339
50	2,092	1,674
60	2,511	2,009
70	2,929	2,343
80	3,348	2,678
100	4,184	3,348
125	5,230	4,184
150	6,277	5,021
175	7,323	5,858
200	8,369	6,695
250	10,461	8,369
300	12,553	10,043
350	14,645	11,716
400	16,738	13,390
500	20,922	16,738
600	25,106	20,085
700	29,291	23,433
800	33,475	26,780
900	37,659	30,128

Table 1.1 Rated Capacity

The Sellers Immersion Boiler is a single-pass design, with tubes only, and no furnace chamber or turnaround. It does not require thermal protection controls or other special startup sequencing. It can be driven to high fire after startup.

1.2. Model Designation

The model designation provides some basic information about the unit. In the model number, the first number indicates the boiler horsepower (BHP) of the unit.

The next number/letter sequence defines the design pressure, as stated in Figure 1.1.

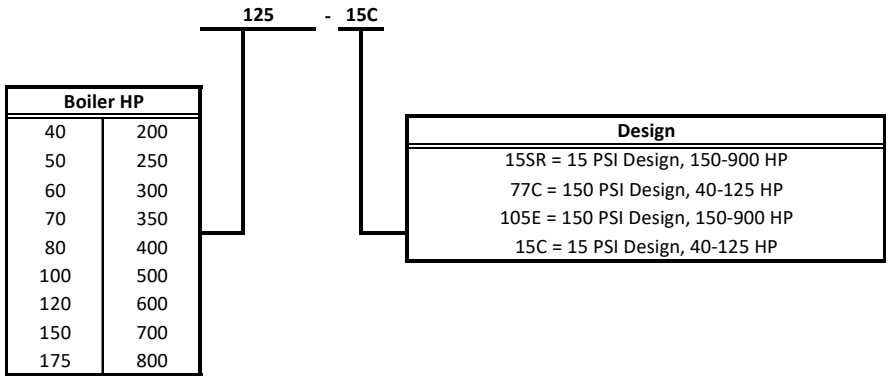


Figure 1.1 Model Numbering

1.3. Nameplate Information

Each boiler has a nameplate that contains critical information about the boiler. The nameplate is located on the face of the burner and looks like Figure 1.2.

The information on the nameplate is critical for the operation, parts and maintenance of the equipment. Here is a more detailed description of the information:

- Model Number – see Section 1.2
- Max Design Pressure: The design pressure of the vessel, used to determine the design of the vessel.
- Serial Number: A unique number assigned by Sellers to the specific boiler.
- ASME Number: Sellers' ASME certificate number
- National Board: A unique number recorded by the National Board of Boiler and Pressure Vessel Inspectors.
- Input – BTU/hr.: The maximum energy input of the burner, expressed in BTU/hr., and based on 80% efficiency.

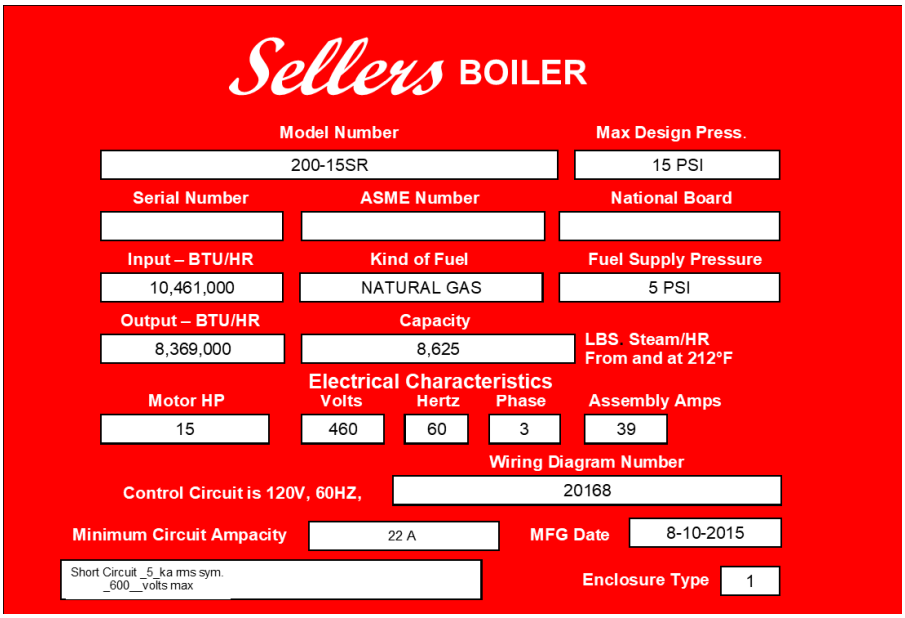


Figure 1.2 Nameplate.

- Kind of Fuel: The fuel specified for this unit, which is used to design the burner components.
- Fuel Supply Pressure: The gas pressure to the inlet of the gas train.
- Output: The energy output of the unit, in BTU/hr.
- Capacity: The rating of the vessel in pounds of steam per hour, from and at 212 °F.
- Motor HP: Rated motor HP of the combustion air fan.
- Electrical Characteristics
    - Volts: The voltage rating of the electrical supply
    - Hertz: The frequency rating of the electrical supply, usually 60 Hz.
    - Phase: The number of phases in the electrical supply, usually 1 or 3
    - Assembly Amps: Current rating for the boiler/burner assembly
    - Control Circuit is 120 Volts, 60 Hz.
    - Wiring Diagram Number: Drawing number of the wiring diagram for the unit.
    - Minimum Circuit Ampacity: Minimum ampacity of the main conductors feeding the unit.
- MFG Date: The date this unit was completed, and fire tested.
- Enclosure Type: NEMA Class of enclosure
- Additional Info: Short Circuit Current Rating

1.4. Your Complete Manual

This manual provides information on your Sellers equipment. In addition, separate product cut sheets are provided for the purchased components used in this product. At a minimum, this would include the flame safeguard, fuel control valves, safety limit controls, water level controls, and steam valves.

A wiring diagram and parts list are supplied with the boiler manual. The wiring diagram must be used to properly wire the boiler and connect other related equipment. The parts list should be used when ordering spare or replacement parts.

A copy of the fire-test report is included with the boiler manual packet, placed in the control panel on the face of the burner assembly. The fire-test report is a document that provides the information obtained at the initial test fire of the unit at the factory, including the fuel inputs, combustion settings, pressures, and motor amps. It contains several key details that can be very helpful in setting up the boiler in the boiler room application.

⚠ WARNING

DO NOT ATTEMPT TO OPERATE THIS PRODUCT UNTIL YOU HAVE READ AND UNDERSTAND THE COMPLETE MANUAL. RUNNING THIS EQUIPMENT WITHOUT A PROPER UNDERSTANDING OF HOW TO PROPERLY START, ADJUST AND OPERATE IT CAN RESULT IN DAMAGE, INJURY OR DEATH.

1.5. Parts and Warranty

Parts, warranty information, and field service support are available from your local Sellers Representative. For a list of Sellers Representatives, please visit the Sellers website at www.sellersmfg.com. To facilitate a quick response, please have the sales order number and other information on the unit available.

The Startup Report is required to be filled out and submitted to Sellers within 4 weeks of the initial startup of the unit to qualify for warranty. The Startup Report form can be found in this manual, and additional copies can be obtained from Sellers. After startup and completion of this form, submit the document to Sellers by email at info@sellersmfg.com.

1.6. Acronyms and Definition of terms

The following acronyms and abbreviations are used in this manual:

ALWCO: Auxiliary low water cutoff

ASME Code: A code written by the American Society of Mechanical Engineers that covers boiler and piping design.

ASME CSD-1: An ASME code that covers controls and safety devices for automatically fired boilers.

ASME B31: ASME code for pressure piping

BHP: Boiler Horsepower (1 BHP = 33,475 BTU/hr.)

Capacity or Rated Capacity: The maximum input or output of a boiler, which can be in BTU/hr. or pounds of steam/hr.

Combustion Chamber Pressure: The pressure in the chamber (combustion chamber) where the nozzles fire into the tubes. This is also where the secondary air is injected to support the pilot and main flame.

Combustion Controls: Controls used to manage the flow of air and fuel to provide different firing rates.

Design Pressure: The pressure used for the design of the pressure vessel and related components.

Draft: The pressure measured at the outlet of the boiler, where it is connected to the stack. This pressure should be maintained at a pressure of +/- 0.1” wc.

Flame Safeguard: The controls used to ensure that the combustion process is managed in a safe manner.

Inches Water Column (“ wc): Pressure measured in inches of water (1PSI = 27.7” wc)

Input: The energy input into the boiler, in BTU/hr. or MBH (1000s of BTU/hr.)

Manifold: The chamber downstream from where the fuel and air are mixed, and upstream from where they enter the nozzles.

Manifold Pressure: The pressure inside the manifold chamber.

Manual Reset Switch: A switch which will remain tripped once triggered and requires a manual reset.

Manufacturing Date: The date the boiler manufacturing was completed.

MAWP: Maximum allowable working pressure

Maximum Input: The maximum fuel input for this unit, expressed in BTU/hr.

Minimum Input: The minimum fuel input for this unit, expressed in BTU/hr.

MS #: Manufacturers serial number, a unique number assigned by Sellers to the boiler, and registered with ASME.

Nameplate: A plate containing key boiler information (see Section 1.3).

National Board Number: A unique sequence number assigned by Sellers and registered with the National Board.

NFPA: National Fire Protection Agency

NFPA 54: National Fuel Gas Code

NFPA 70: National Electric Code (NEC)

NFPA 85: Boiler and Combustion System Hazard Code

NPS: Nominal pipe size

NPT: National pipe thread, tapered.

Output: The energy output of the vessel in steam, expressed in BTU/hr. or BHP. Often the boiler output is approximated at 80% of the input, but actual efficiencies can vary.

PLWCO: Primary low water cutoff

Primary Air: Combustion air mixed with fuel before the combustion process.

PSI: Pressure in pounds per square inch.

Secondary Air: Air that is added to the combustion process after the combustion has started.

Section I: ASME code that covers high pressure (over 15 PSI steam and 160 PSI or 250 °F hot water).

Section IV: ASME code that covers low pressure (up to 15 PSI steam and 160 PSI or 250 °F hot water).

Serial Number: A unique manufacturer's number assigned to each boiler for identification.

VOLTS, HERTZ and PHASE: Refers to the electrical supply characteristics provided to the boiler.

2. EQUIPMENT AND COMPONENT DESCRIPTION

2.1. General Description

The Sellers S-Series boiler is a packaged fire-tube boiler with an integral burner, manufactured by Sellers Manufacturing Company. It is intended for commercial heating and process applications, and is offered as a steam boiler in sizes from 40 HP to 900 HP.

The burner is a pre-mix type that fires natural gas, LP, digester gas and other gases. It is a modulating burner. The burner is also offered with an optional low NOx firing for emission levels of 30 ppm or lower (corrected to 3% O_2). The burner and boiler package are listed by Underwriters Laboratories (UL) for up to 900 horsepower.

The boiler and burner are pre-assembled and shipped as a packaged unit, and include the gas train, combustion air fan, burner controls, vessel controls, safety valves and many other components as listed below. The boiler is test-fired at the factory, and the results of that test firing are recorded on the "Fire Test Sheet" which is included in the manual.

The standard boiler is provided with a Siemens LMV5 parallel positioning control which uses a servo to modulate the air damper and fuel valve.

The burner uses a ribbon pilot, which provides a small pilot under each nozzle. The pilot ribbon runs across the burner front as well as up and down the burner front. At pilot ignition, a spark ignites the ribbon pilot at one end, and this flame spreads across the burner face to the far corner, where the flame is proven by a flame rod. On main flame, a flame rod on one of the nozzles is used to prove that the main flame is established. The pilot stays on as long as the burner is on and cycles off when the burner turns off.

The Sellers S-Series boiler has several unique differences from conventional fire-tube boiler. The primary difference is that the vessel is a single-pass boiler (no furnace) with individual burners firing into the 2" tubes in the vessel. This means there is no furnace or turnaround chamber. There is also no refractory or baffles to direct flue gases.

Because there is no furnace that will expand at a different rate from the tubes in the other passes, there is no thermal shock. Every tube inside the vessel receives the same heat input and has the same expansion rate, so there is no uneven heating to cause thermal stress. Sellers' boilers can be run at high firing rates after startup.

The following section has a list of the main components used in the S-Series boiler and a description of their function.

2.2. Standard Components

1. Burner Assembly – Assembly of the components required to provide the fuel and air for combustion, and the controls to provide safe light-off and control of the combustion process. A more detailed explanation of the internals of the burner is covered at the end of this section. Some of the vessel controls are also included in the burner controls.
2. Blower Motor - Drives blower fan to provide the air required for combustion. All motors are 3500 RPM. An open drip-proof (ODP) style motor is provided as a standard offering, but other versions are available as options. A totally enclosed fan-cooled (TEFC) motor would typically be used for dirty or outside environments.
3. Air Proving Switch – Safety interlock switch that measures the pressure developed by the combustion air fan and opens if that pressure drops below its setting. It prevents the ignition sequence or shuts off the burner under conditions of insufficient combustion air pressure (automatic reset device).
4. Pilot Shutoff Cock – Ball valve that is used to manually control the pilot gas volume or isolate the pilot gas flow. The actual adjustment of the pilot gas flow is done by adjusting the pilot gas pressure regulator.
5. Pilot Gas Pressure Regulator – Manually adjusted pressure-regulating valve that provides a constant gas pressure to the pilot. It is the primary means of controlling the pilot gas flow.
6. Automatic Pilot Gas Valve (not shown, downstream of pilot regulator) – Solenoid valve that automatically controls the pilot gas supply in response to burner operation through the flame safeguard sequence. The pilot remains on through the main flame operation in addition to the pilot proving period.

7. Main Gas Shutoff Cock – Manual valve used to isolate the main gas supply to the burner assembly. It is installed upstream of the main gas train components.
8. Main Gas Pressure Regulating Actuator – A manually adjusted pressure-reducing actuator that provides a constant gas pressure to the main burner. This is attached to the safety shutoff valve.
9. Main Safety Shutoff Valves – Electric valves (motor and/or solenoid) that control gas supply to the main burner in response to the operating sequence of the controls, including the flame safeguard. They can also be integrated into the gas pressure regulator as shown in Figure 2.1 (item #8).
10. Low Gas Pressure Switch (if provided) – A gas pressure switch that prevents the operation of the burner in the event of unsafe low gas supply pressure. This is a manual reset device which requires that the reset button be pressed to allow the burner to operate.
11. High Gas Pressure Switch (if provided) – A gas pressure switch that prevents the operation of burner in the event of unsafe high gas supply pressure. This is a manual reset device which requires that the reset button be pressed to allow the burner to operate.
12. Normally Open Vent Valve (if provided) – Provides unrestricted vent to atmosphere between dual main automatic safety gas valves when burner is off. This is not normally used with propane (or LP) because it is heavier than air and will tend to pool at a low point, which could explode.
13. Leakage Gas Shutoff Cock – Manually controls main gas supply to the burner assembly. This valve is also sometimes called the safety valve because it is used to manually control gas flow on initial startup, and quickly shut off gas flow if combustion is not correct. It also allows for manual leak testing of automatic safety gas valves. It is installed downstream of the last automatic safety gas valve.

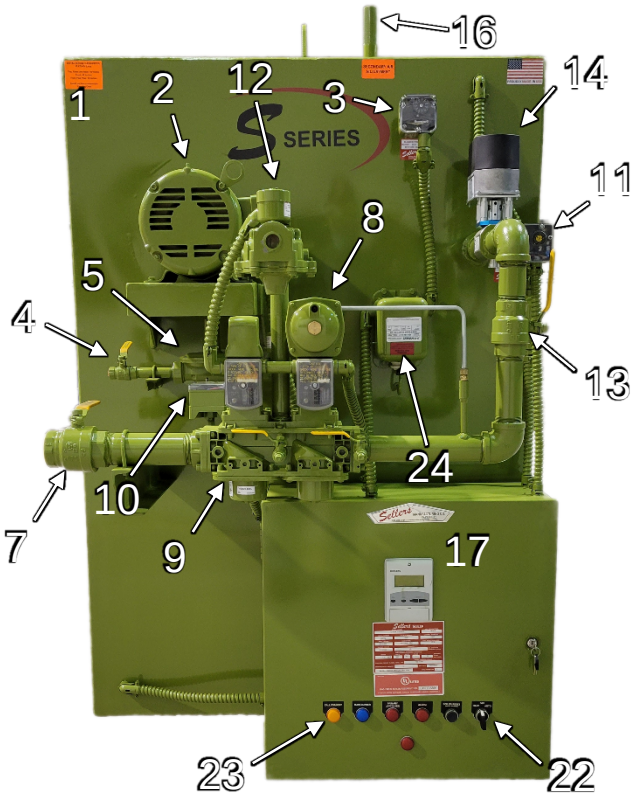


Figure 2.1 Front View

14. Gas Control Valve and Servo – A combination of a butterfly control valve and a servo motor that modulates the valve to control the volume of gas to the main burner. This valve is controlled in combination with the air damper to provide the proper fuel-air ratio to the burner nozzle. The butterfly control valve is sized for the specific application, based on the flow rate and available pressure.
15. Combustion Air Damper and Servo – A combination of a modulating air control box, which changes the volume of total air supplied to the burner, and a servo motor, which positions the damper. The servo is controlled in combination with the fuel valve to provide the proper fuel-air ratio to the burner nozzle.
16. Secondary Air Adjustment(s) – A manual adjustment (and lock) for controlling the secondary air. On smaller boilers, a single adjustment may be mounted on top of the burner assembly. This will change how much air is used in the primary and secondary air flow.

17. Control Panel – Houses and protects electrical controls, wiring, and provides terminals for wiring connections. See details below in Figure 2.4.
18. Manufacturers Nameplate (not shown) - Provides identification and rating information specific to the boiler, see Section 1.2.
19. Flame Safeguard – The flame safeguard controls the sequence of operations needed for safe operation of the burner. The flame safeguard controls the fuel and air flow rates from low fire to high fire and through modulation.
20. Control Circuit Transformer - Converts primary electric supply voltage to 120 VAC single phase for the boiler control circuit.
21. Blower Motor Contactor/Overload – A device which starts or stops the blower motor in response to flame safeguard sequence. It also provides overload protection for the motor.
22. On/Off Control Switch - Provides manual on/off control of the boiler (sometimes called safe-start switch).
23. Indicating Lights - Provides visual signal to verify the current operating status of boiler.
24. Ignition Transformer - Provides high voltage electric output to ignition electrode for safe ignition.

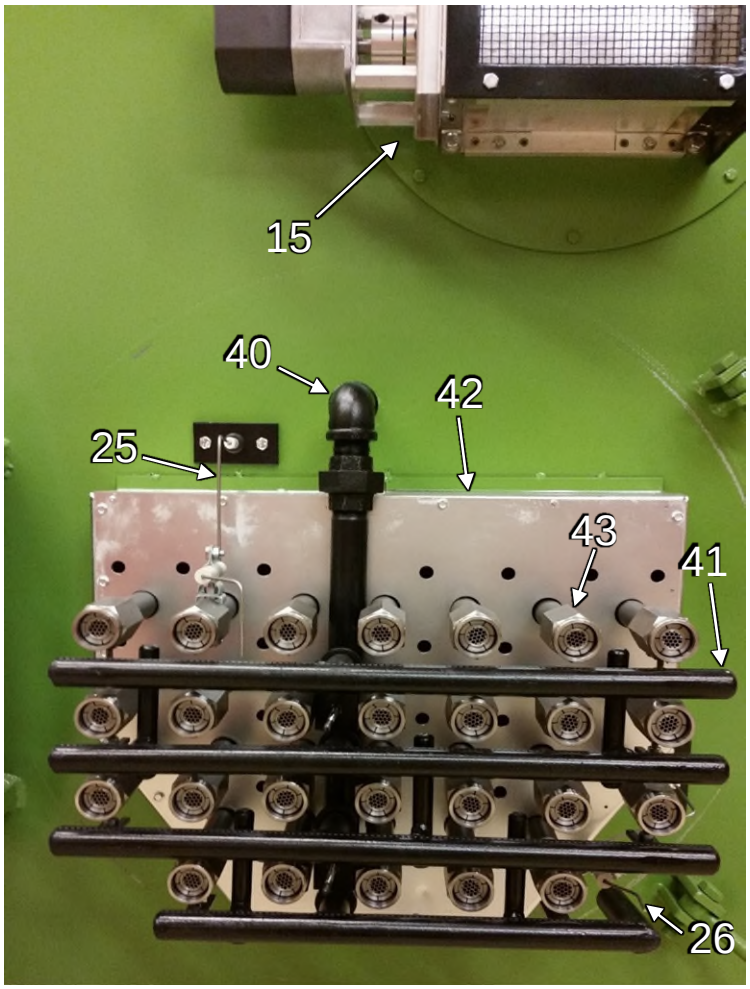


Figure 2.2 Burner

25. Ignition Electrode - Provides spark for safe pilot ignition.
26. Pilot Flame Proving Electrode - Senses presence and proper location of the pilot flame for safe main burner ignition. The proving rod is opposite the ignition electrode, so that the pilot must ignite across the full burner face to prove all the pilots have ignited.
27. Main Flame Proving Electrode - Senses presence of main burner flame in proper position for safe main burner operation. (Not furnished on boilers less than 60 HP.) (not pictured - same as 26 but located on main burner nozzle)
28. Structural Steel Base - Supports entire boiler for handling and rigging, and evenly distributes boiler weight.
29. Lifting Eyes – Connection points for lifting the boiler. See Section 3 for details.

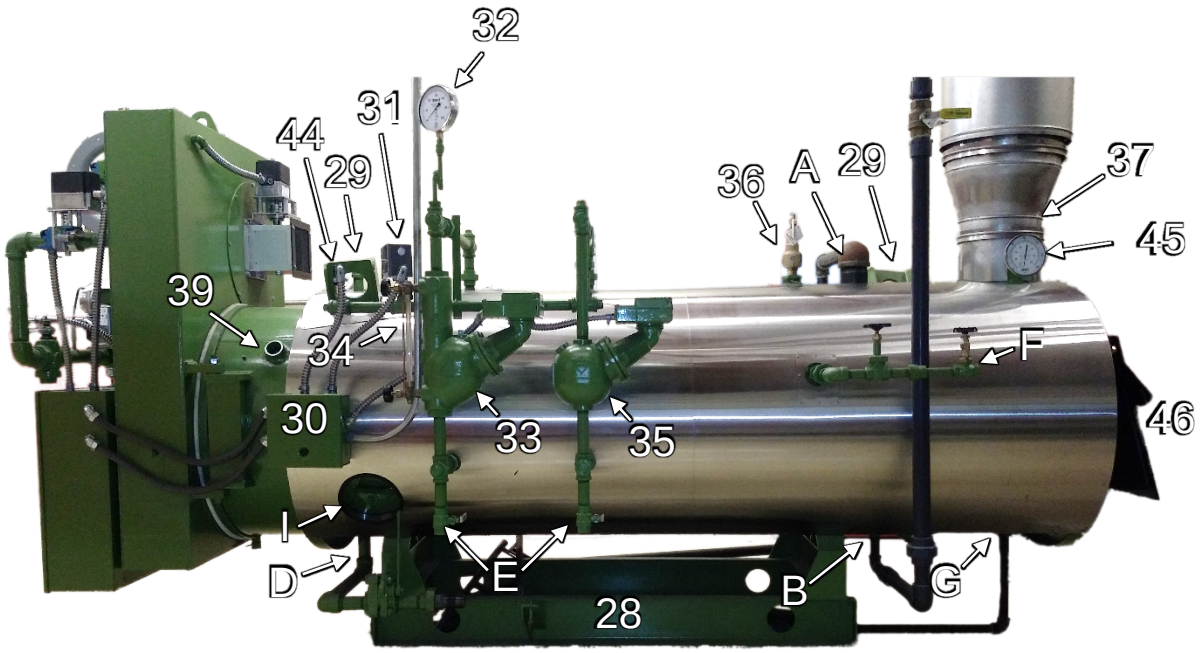


Figure 2.3 Side View

30. Electrical Supply Junction Box - Provides convenient primary electrical supply connection to the boiler. This is the only location to bring electrical connections to boiler. Wiring directly to the control panel will prevent you from being able to open burner manifold and service combustion chamber.

31. High Limit Pressure Control – A manual reset pressure switch that monitors the steam pressure and will shut down the boiler if that pressure is exceeded. Once the switch is tripped, it must be manually reset to allow the burner to operate. The pressure limit is adjustable.

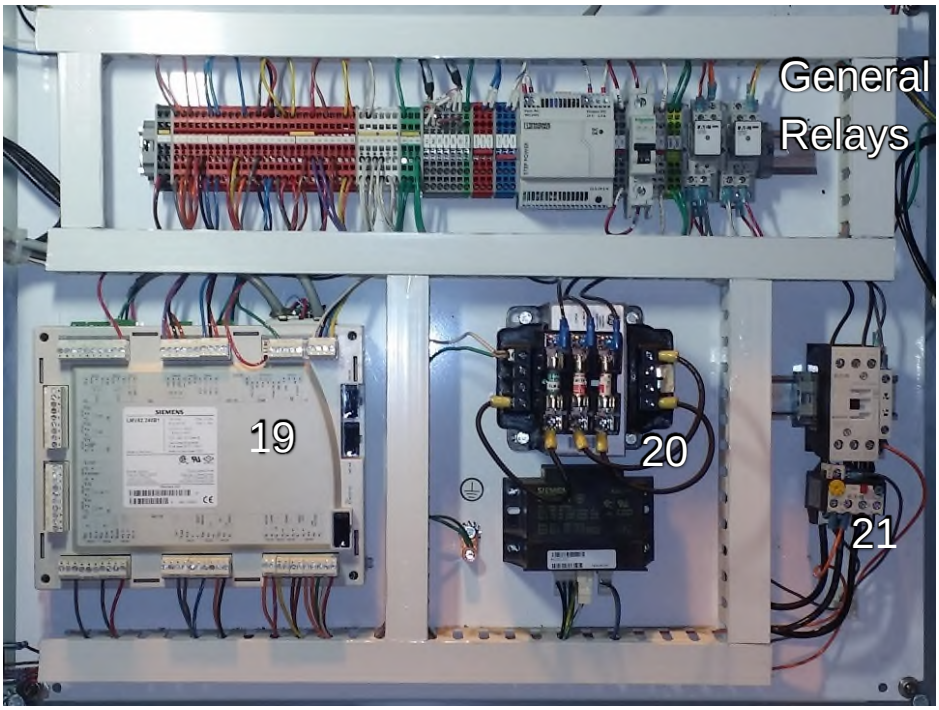


Figure 2.4 Control Panel

32. Pressure Gauge - Provides visual verification of boiler operating pressure.
33. Pump Control/Primary Low Water Cutoff – (PLWCO) Provides on/off pump operating contacts for proper level control in the boiler and prevents operation of the burner assembly in the event of unsafe water level condition (automatic reset device). The control uses a float to activate switches for the pump control and low water cutoff. This control requires frequent blowdown maintenance and regular inspections for continued safety.
34. Water Gauge Set – Provides visual indication of the water level in the water column and the boiler shell.
35. Auxiliary Low Water Cutoff – (ALWCO) Prevents operation of burner assembly in the event of unsafe water level condition. (manual reset device). The ALWCO can be a float control switch (as shown), or an electronic control mounted in the center of the vessel. The float control requires frequent blowdown maintenance and regular inspections for continued safety.
36. Relief Valve(s) - Relieves internal pressure in boiler if component failures allow an unsafe pressure condition to develop. Once the boiler is installed, it should be piped to a safe point of discharge (see Section 3 for details).
37. Stack Outlet - A round stack connection is provided at the rear of the boiler for connection to the stack or breeching. The maximum stack weight that can be supported by the boiler is 1000 pounds on boilers up to 80 HP and 2000 pounds on boilers larger than 80 HP. See Section 3 for other design considerations for stacks and breechings.
38. Blast Shield (optional, not shown) - Provides adequate space around the relief door prohibiting anyone from being in the range of motion of the relief door in case it was to open and relieve pressure due to a combustion explosion.
39. Combustion Sight Glass - Provides visual inspection of pilot and main burner condition. There are several sight glasses (more on larger units) to visually inspect the pilot and main flame combustion.
40. Pilot Gas Header – Delivers pilot gas to the runner pilots.
41. Runner Pilots – Provides ribbon flame below all main burner nozzles for ignition. This pilot remains on during the burner firing.
42. Secondary Air Box – A pressurized box that has numerous small holes for uniform distribution of secondary air to the pilots and main flames.
43. Main Burner Nozzles – Flame retention type nozzles deliver pre-mixed air and gas across runner pilots and into the fire tubes for combustion.

Figure 2.5 Relief Door

44. Pressure Transducer – Provides 4-20 mA signal to control the burner in response to load changes. See Section 5 for details.
45. Flue Temperature Gauge – Provides visual indication of the flue gas temperature.
46. Relief Door – A combustion relief door is provided at the rear of the unit. It provides a relief opening in the event of a combustion explosion. The room layout should allow an open space behind this door that will not expose individuals to this area in the rare case that it may open and release hot gases. The door has a gasket seal that must be maintained to provide a tight seal and prevent air from entering, which would result in a false high excess oxygen reading. This is especially true if oxygen trim unit is used for combustion tuning, and if there is a high negative draft that would pull in more air. (Fig 2.5)

2.3. Standard Boiler Openings

A. Steam Outlet Nozzle – Opening from boiler into steam system.

B. Boiler Feed Water Connection - Opening to boiler for feed water from boiler feed system.

C. Manual Fill Connection (not seen) - Opening to boiler for initial manual fill. Usually in the bottom center, under the skid (300 Horsepower and larger.)

D. Bottom Blowdown Connection - Opening for bottom blowdown or complete draining of boiler.

E. Water Column Blowdown Connection(s) – Opening for float type low water level control(s) blowdown.

F. Surface/Continuous Blowdown Connection – Opening for surface blowdown or skimmer system.

G. Rear Condensate Drain - Opening for draining initial condensation of water vapor from flue gases out of rear of boiler.

H. Manhole Opening (if supplied) - Full size opening for access to water side of boiler for inspection and cleaning.

I. Handhole Opening(s) - Small opening for access to water side of boiler for inspection and cleaning.

J. Relief Valve Openings – Opening for the discharge of the relief valve outlet to safe terminating point. The number and size of the openings are based on operating pressure.

2.4. Burner Internal Components

The air damper is used to regulate the quantity of air flow for combustion, to match the fuel flow for the proper fuel-air-ratio. Inside the housing, the air inlet chamber (from the air damper to the inlet cone) is isolated from the pressurized impeller outlet. The impeller is connected to the combustion air motor.

The pressurized air is channeled across the top of the burner, where secondary air adjustments are used to allow some air to flow to the secondary air box. Secondary air is used to provide combustion air for the pilot. Small burners only have one secondary air adjustment while larger units have two adjustments.

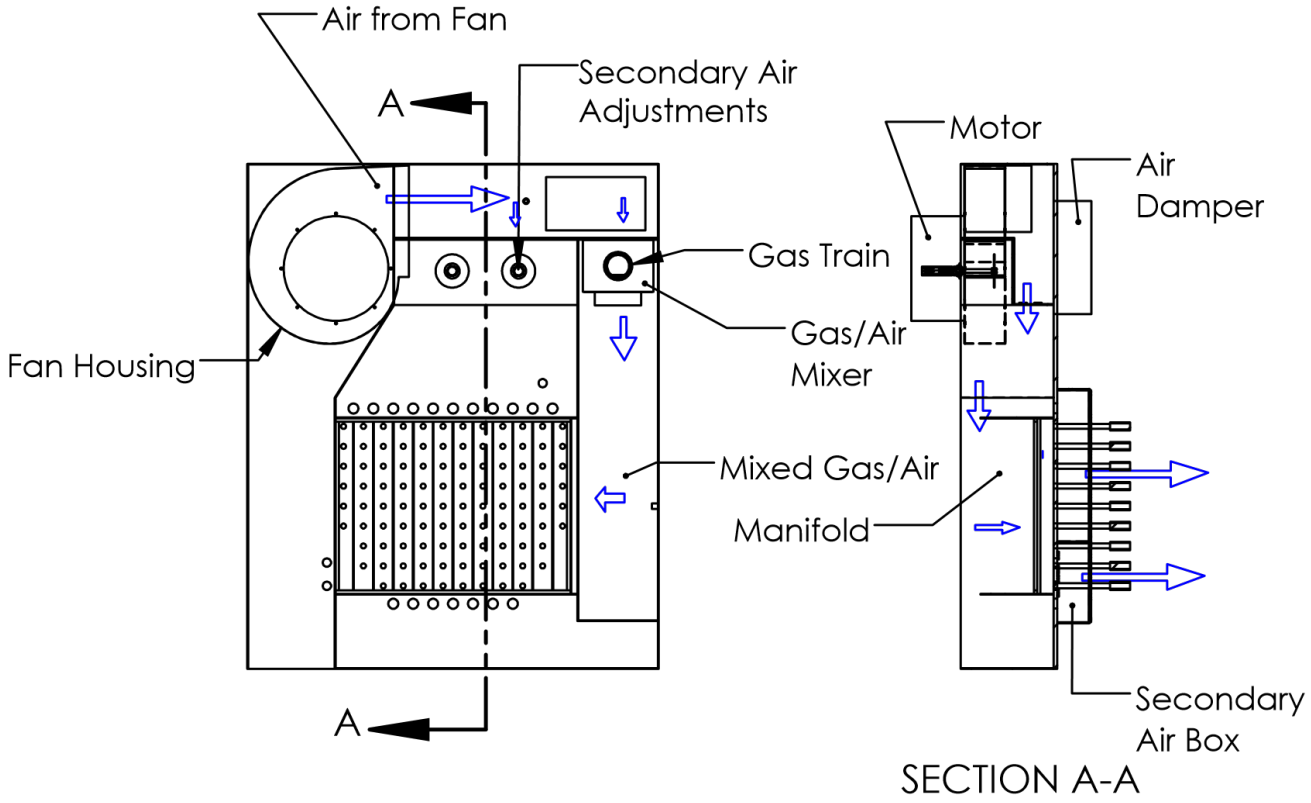


Figure 2.6 Typical Air Movement

As the pressurized air flows across the top of the burner, it is channeled down along the right side, and is forced through the mixer, where the fuel is mixed with air. The fuel-gas mixture is delivered from the gas train, and the flow is regulated by the butterfly control valve to match the air flow. From the mixer, the fuel-air mixture is channeled into the manifold feeding the nozzles.

3. INSTALLATION

Before proceeding with installation, locate the *Pre-Startup Checklist*¸ found in the front of this manual. Once the checklist is filled out, it must be returned to your startup technician.

Prior to starting, all technical literature should be assembled and reviewed. At a minimum, for a steam boiler installation, this should include the boiler, flame safety controls, feedwater system (piping and controls), blowdown equipment and any other additional equipment that may be used like draft controls, combustion trim systems, building management controls, and steam piping. All these systems must work together for the unit to work properly and efficiently.

This equipment shall be installed in accordance with state and local requirements, and the ASME and National Electric Code (NEC) as well as any insurance codes and requested regulations.

Note to Installer: The main power disconnect for this equipment must be clearly labeled and placed within sight of the operating system and equipped with lockout provisions.

3.1. General Considerations

The installer should contact the local gas utility regarding available supply pressures, limitations on allowable pressures in the building, general piping requirements and applicable codes, restrictions and regulations.

Most states require that the boiler be inspected and/or registered with the state. In some cases, there may be environmental requirements for inspection and/or listing as well.

If the boiler is in a dirty environment, consideration should be given to TEFC motors. Debris can build up and eventually plug smaller orifice holes (approximately 3/32" diameter). The combustion air should be filtered by adding a filter to the boiler room air handler or vent. Do not install a filter on the boiler primary air intake. Additional maintenance will also be required for the fan and air passageways if the unit is run in a dirty environment.

If the boiler is designed to be located outside, the unit must be protected from extreme temperatures, humidity, and weather. These conditions must be identified so that the controls are designed for that environment. If the temperature can fall below freezing, all water-related components must be protected. In addition, special controls will be required because of these conditions.

The boiler room floor should be designed to support the full weight of the boiler and water, which is given in Table 3.1, plus any connected components. A raised concrete pad or piers should be provided for the boiler base. The base dimensions are also provided in Table 3.1. Make certain the base assembly is level. If the boiler is to be mounted on a mechanical structure, the structure must be rigid enough to prevent vibrations from causing problems within the building. The combination of rotating equipment and the inherent vibrations in combustion can cause harmonic issues with structural members.

There should be an engineering review of the installation to ensure that there is sufficient space to support each of the following:

- There should be space to walk around the unit to access and maintain the components on the boiler.
- The burner is hinged and can swing open, but there must be sufficient clearance to allow this to occur. See Table 3.1 for front door swing clearance.
- The rear relief door can open on a combustion backfire, and there should be sufficient space for this to occur without hitting anything.
- There should be enough space to replace the tubes at some point in the future. This can be done from the front or the back of the boiler, and the space required is listed in Table 3.1. This can be accomplished with an overhead door or other approach that would yield this clearance.

Boiler HP	Door clearance		Tube Removal		Base frame dimensions			Shipping Weight (lbs.)	Flooded Water Capacity (gal)
	Front door swing	Rear relief door swing	From front door	From rear door	Width	Length	Distance to hinge		
40	39	22	73	71	24	60	20	3,852	229
50	39	22	73	71	24	60	20	5,149	222
60	40	22	73	71	24	60	20	5,207	218
70	46	26	73	71	24	60	20	5,247	323
80	46	26	73	71	30	60	20	7,021	317
100	53	30	66	72	30	60	26	7,060	437
125	53	30	66	72	36	60	26	9,436	421
150	62	36	66	72	36	60	26	9,557	560
175	62	36	66	72	36	60	26	9,669	545
200	67	40	66	72	42	60	26	12,084	703
250	67	40	88	90	42	104	3	15,036	869
300	74	43	88	90	48	104	3	19,187	1079
350	88	43	88	90	48	104	3	19,289	1046
400	90	46	88	90	54	104	3	22,342	1282
500	96	50	88	90	57	104	3	25,874	1510
600	101	48	88	90	63	104	3	30,717	1763
700	106	50	88	90	66	104	3	35,633	2041
800	114	52	88	90	72	104	3	40,900	2345
900	114	60	88	90	84	104	3	49,480	2676

Table 3.1 Dimensions and Weights

3.1.1. Receiving the Boiler

The equipment should be inspected prior to installation for missing parts or damage, which could be physical, moisture-related or rust. Any damage and missing parts should be addressed prior to installation. Check the parts list against the bill of lading to make sure all parts have been received. If in a busy construction area, make sure to identify the parts that belong to the boiler so they can be retrieved later.

If the boiler has been stored outside for any length of time, the inspection should include the inside of cabinets and some electrical components to make sure they did not receive water damage. The boiler warranty does not cover water damage.

It is the responsibility of the receiving party to properly inspect the unit for damage at the time it is received, and to file appropriate claims with the shipping company to recover damages.

3.1.2. Positioning the Boiler

Prior to starting the installation, a general overview of the equipment should be made. Check the location of access doors and ensure that they can function properly when all equipment is installed. The burner and control panel should have enough clearance for the operator to monitor, inspect, and perform maintenance.

Locate the boiler with due regard to local code regulations and insurance requirements. Local codes and specifications will apply to such conditions as foundation design and proximity to flammable materials. Adequate clearance must be provided for normal service operations.

Provide enough unobstructed space at the firing and exhaust ends of the boiler to fully open the hinged main burner assembly and the back plate (if hinged). This will allow convenient access to all internal areas for normal inspection and service operations. The minimum clearance necessary for opening the hinged boiler assemblies is listed in Table 3.1.

Provide room at either the firing or exhaust end of the boiler for possible future tube replacement. The minimum clearance necessary for easy removal and re-installation of firing tubes is listed in Table 3.1. This can be accomplished using an overhead door that can be opened to provide the required length.

Verify that the boiler is sitting level. If the boiler is not level, add spacers to make it sit level. This is critical for allowing uniform water coverage over the full length of each tube.

When unloading the boiler, use the lifting eyes provided. DO NOT USE a sling or forklift under the shell or attach cables to the legs or base rails. This could damage the boiler. See Figure 3.1.

If the boiler is to be winched into position, use trucks under the boiler legs, and winch by connecting to the boiler legs. Do not place loads on the center or ends of the base rails.

The rear of the boiler has a combustion relief door that is designed to relieve over-pressurization that can be caused by improper combustion, including a hard light-off or gas side explosion.

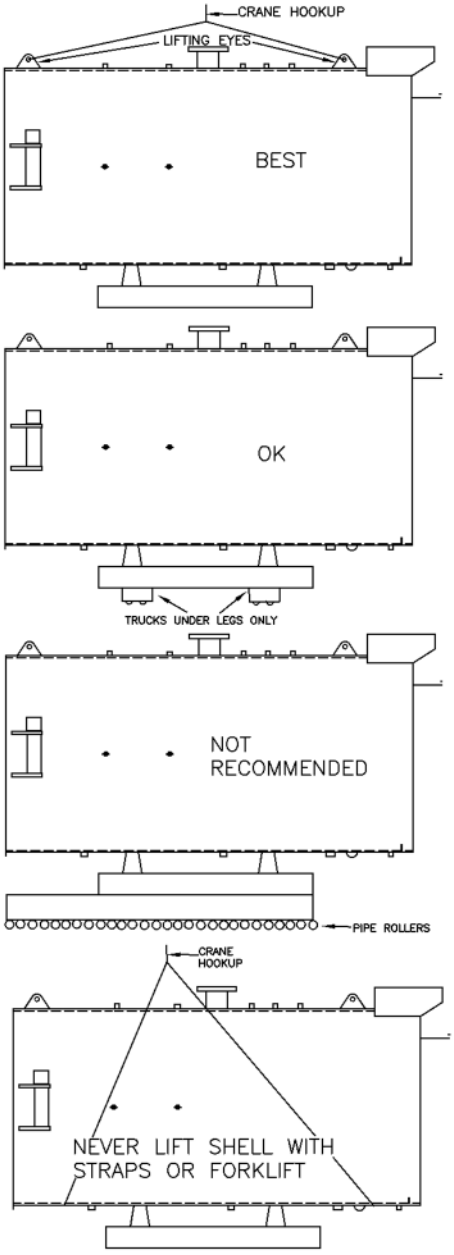


Figure 3-1

DANGER

THE COMBUSTION RELIEF DOOR MAY OPEN AND RELEASE HOT GASES. INDIVIDUALS SHOULD NOT BE IN THIS AREA, AS IT CAN RESULT IN PERSONAL INJURY OR DEATH.

3.1.3. Installation of Ship Loose Items

The steam gauge is the only component normally shipped loose. It is stored in the control panel during shipment.

3.2. Combustion Air Requirements: The Forgotten Element in Boiler Rooms

WARNING

THE BUILDING DESIGN MUST PROVIDE SUFFICIENT AIR FOR COMBUSTION AND OTHER EQUIPMENT WITHOUT RESTRICTION. FAILURE TO PROVIDE SUFFICIENT AIR CAN RESULT IN HIGH FUEL COST, EXCESSIVE EMISSIONS, EQUIPMENT DAMAGE, EXPLOSION, PERSONAL INJURY OR DEATH.

Many states have regulations that determine the requirements for combustion air supply openings, and these regulations must be followed. There are other sources of information on combustion air openings, including the ABMA (American Boiler Manufacturers Association) and NFPA-54. If there are no requirements for combustion air, the following is recommended by Sellers.

Sellers recommends a total minimum air supply opening of approximately 250 square inches per 1,000,000 BTU/hr. of input. This minimum cross-sectional area can increase with barometric dampers, forced ventilation systems or other equipment. Air can be provided through louvered panels in window or door openings or through specially prepared openings in the walls of the room. Remember that the open area for air flow is reduced with louvers, and the size must be increased to allow for this. It is also recommended that multiple openings be provided, with some located higher and some lower to improve ventilation. The effect of exhaust fans in the general area must be considered as they can greatly increase the opening requirements. A further explanation of this can be found in an article written by the National Board, entitled “Combustion Air Requirements: The Forgotten Element in Boiler Rooms.”

3.3. Steam Boiler Connections

All steam and water piping to the boiler must comply with all state and local code requirements and the ASME code. The boiler openings are labeled at the factory. The specification sheet also lists the boiler openings. Proper piping support must be used. Do not use the boiler to support the piping.

The requirements for the steam piping include the minimum equipment defined by the ASME codes and operational equipment that should be defined by the boiler room designer. The ASME code defines requirements for isolation of the boiler, especially to allow for safe maintenance of the vessel. The other equipment may include header systems to connect multiple boilers, pressure reducing valves to support different operating requirements, and components like back pressure regulators to limit the steam flow on startups.

The steam boiler openings are identified in section 2.3. Any unused connection must be plugged.

3.3.1. Feedwater Piping

The feedwater piping supplied by Sellers includes a stop valve at the boiler and a check valve. Additional controls are required to provide and control the feedwater to the vessel, including a control valve, pumps, storage and water treatment.

A feedwater system includes a combination of water treatment processes, condensate recovery, pumping equipment and controls used to regulate the flow of feedwater to the boiler. Each feedwater system is designed to handle the specific application, which can vary based on the amount of condensate return, quality of water used and hours of operation.

WARNING

FEEDWATER MANAGEMENT IS CRITICAL TO THE OPERATING LIFE OF THE BOILER. FAILURE TO PROVIDE CLEAN WATER FREE OF CORROSIVE ELEMENTS WILL RESULT IN PREMATURE FAILURE OF THE BOILER

An additional connection is provided in the vessel for manually filling the boiler. This can be connected to the boiler feed system with a manual shutoff valve, to fill the boiler manually. Manual fill opening only available on 300 Horsepower and larger.

3.3.2. Steam Piping

The ASME code as well as other codes must be followed in the piping system design. These requirements are different depending on the pressure rating, number of boilers and if there are manways in the boilers. As a minimum, the ASME code requires a stop valve at the outlet of each boiler, and for multiple boilers connected to a common steam header, stop check valves are also required on each boiler. These valves must be rated for the application.

All piping shall be designed to allow for expansion and contraction. They must also be supported independently to prevent transmitting stress to the boiler.

The steam outlet of the boiler is sized to prevent water carryover at the expected operating pressure of the unit. If the pipe size is too small, it can result in high steam velocities which would carry entrapped water along with the steam, and in some cases, cause the water to swell and become pulled into the steam nozzle. This may not be the correct size for some control valves, and a spool piece may be required to obtain pipe size changes to support each function.

The maximum steam flow should be limited to the rating of the boiler. High instantaneous loads can result in high steam flow rates that can cause water carryover and "Priming". If there are operations like batch loading of a large steam coil, the feed valve cannot simply go open without causing a very high steam flow rate. Adding a back-pressure control valve or slow opening valve are ways to limit the steam flow rate.

3.3.3. Blowdown Piping

The boiler can be equipped with optional blowdown piping. For high pressure steam, the bottom blowdown piping will have a fast-opening valve and a slow opening valve connected to the single connection at the bottom of the vessel. Low pressure boilers have just one slow opening valve.

The water column comes with a ball valve as standard, and the blowdown piping with a common header is optional. These are connected to the outlet of the bottom blowdown piping as shown in the photo.

The blowdown piping must be connected to a blowdown system. A blowdown system usually has a means of cooling the blowdown water before discharging to the drain. Some blowdown systems use a heat recovery element. Local codes may dictate the maximum discharge temperatures.

Figure 3.2 Blowdown Piping (Optional)

Sellers provides a skimmer pipe for the surface blowdown on all steam boilers, with a ¾" pipe fitting. This skimmer pipe is a tube that runs horizontally across the surface, with numerous holes to pull water (and floating debris and oil) from the surface to discharge to the drain. Low pressure boilers may be equipped with a 1 ¼" shell opening, but no skimmer pipe. Connect the surface/continuous blowdown connection to the blowdown system. This piping must meet local code requirements and should include at least one suitable valve for continuous blowdown service. This is typically a needle valve with a dial setting indicator. More elaborate surface blowdown systems are available and, if used, should be installed in accordance with the manufacturer's instructions. All valves must be rated for the appropriate temperature and pressure.

⚠CAUTION

PROPER BLOWDOWN OPERATION IS REQUIRED FOR THE SAFE OPERATION OF THE BOILER. FAILURE TO REMOVE SLUDGE BUILDUP FROM THE VESSEL OR THE WATER COLUMNS CAN RESULT IN EQUIPMENT DAMAGE, PERSONAL INJURY OR DEATH.

The surface/continuous blowdown connection should be tied into the blowdown system downstream of both the bottom and water column blowdown valves. These blowdown connections should be fully piped to a properly designed blowdown system so that they can be discharged without posing a safety risk.

3.3.4. Relief Valve Piping

Relief valves are installed to prevent the operation of the boiler above its maximum allowable working pressure. They are sized to relieve all the steam that can be generated at the set pressure of the valve and the energy output of the boiler. For this reason, there can be a wide variety of valves and sizes used to reach this specific capacity.

A discharge pipe shall be used to direct the steam to a safe location to prevent injury. The cross-sectional area of the discharge pipe shall not be less than the full area of the relief valve outlet or the total of the valve outlets discharged into the pipe. The pipe run shall be as short and straight as possible and arranged to avoid any stress on the valve. The discharge piping must be independently supported to prevent adding stress to the valve outlet.

It is good practice to manually open the valve at regular intervals. This is done by lifting and releasing the handle on the valve.

3.3.5. Water Level and Controls Piping

The boiler is equipped with a primary low water cutoff with pump control (PLWCO) and an auxiliary low water cutoff (ALWCO). The standard primary LWCO is a float control that is designed to operate the feedwater valve to maintain the proper water level in the boiler. It also has a switch that will shut down the boiler if the water level drops below a certain level. The PLWCO control is an automatic reset, which means that if the boiler shuts down due to a low level, it will restart when the water level is corrected.

The auxiliary LWCO is normally a second float control but may also be an electronic control mounted on the top center line of the shell. This control is a manual reset, and if shutdown occurs, it will require that the switch be manually reset to allow the boiler to operate. Other controls for high water level, additional auxiliary LWCO, or modulating feedwater control are available as options.

All float controls have a blowdown connection tied into the blowdown system. These controls require frequent blowdown operation to operate properly. The blowdown piping must be connected to a safe discharge blowdown system.

The pressure gauge, high limit (pressure switch) and operating pressure sensor (or pressure switches and modulating control) are installed on a pressure manifold, which is usually tied into the piping of the water level controls. No stop valves are allowed in the piping between the vessel and water level controls or the operating and high limit controls.

Common optional systems can include high water level switches, modulating feedwater level control, and multiple sets of controls which can be used to support day/night setback.

3.4. Gas Piping

The boiler includes a gas train that is designed to control the flow of gas to the burner (determined at the time of the sales order), and the volume of gas needed to make the rating of the boiler. The gas train also provides safety controls as designated by UL and other regulations that may apply.

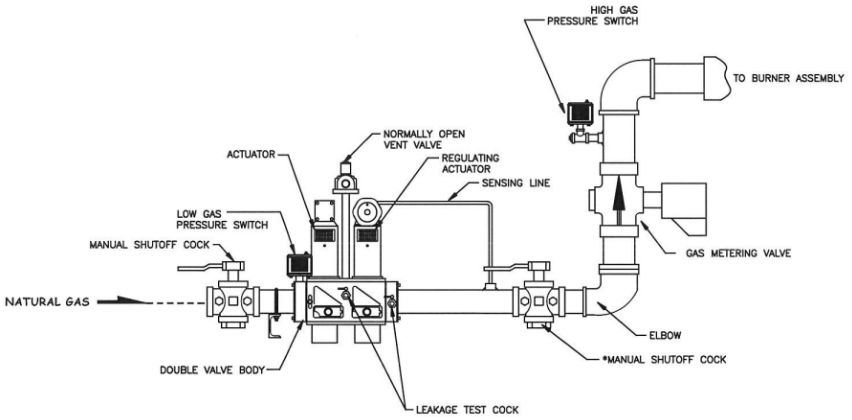


Figure 3.3 Gas Piping

As part of the gas supply to the boiler, a drip leg and main shutoff valve are required upstream of the boiler. Also, a union is required to allow the front door to be opened. The gas train provided by Sellers will include a connection to the pilot train, two safety shutoff valves, a gas pressure regulating actuator (integrated into downstream shutoff valve), a downstream manual valve, and a control valve with driver (servo). Optionally, gas pressure switches, proof of closure switches on the safety valves, and vent valves may be included.

The pilot train includes a shutoff valve, pressure regulator and one safety shutoff valve.

The specific makeup of the main gas train will vary depending on the supply pressure, burner size, and turndown. There are standard gas trains for common supply pressures.

The gas supply pressure at the job site must match the pressures stated on the order. That means that the stated supply pressure (the gas pressure provided to Sellers at the time of the order) must be available at the entrance to the burner gas train when the boiler is off, operating at full capacity, and when other gas equipment is operating on the same gas line.

Table 3.2 indicates the minimum and maximum natural gas pressures for various gas trains, sorted by gas train size and unit size. For dashed values in the pipe size columns, the first number indicates the diameter of the gas valves and upstream piping, and the second value indicates the diameter of the downstream piping after the gas valves to reduce velocities.

Boiler HP	Std Pipe Size (Inch)	Pressure Required (psi)		Boiler HP	Std Pipe Size (Inch)	Pressure Required (psi)	
		Min	Max			Min	Max
40	1.5	1	5	200	1.5"-2"	3	5
					2"	2	
50	1.5	1	5		2.5"-3"	1	
60	1.5	2	5	250	1.5"-2"	4	5
	1.5-2	1			2"	3	
					2.5"	2	
70	1.5	2	5	300	2"-2.5"	3	10
	1.5-2	1			2.5"	2	
				350	2"-2.5"	4	10
80	2	1	5		2.5"	2	3
				400	2.5"-3"	3	10
100	1.5	1	5		3"	2	
				500	2.5"-3"	3	10
125	1.5"	2	5		3"	2	
	2.5"-3"	1		600	3"-4"	3	10
					4"	2	
150	1.5"	2	5	700	3"-4"	3	10
	2.5"	1			4"	2	3
				800	3"-4"	4	10
175	1.5"-2"	3	5		4"	2	3
	2"	2		900	3"-4"	5	10
	2.5"-3"	1			4"	2	4

Table 3.2 Gas Train Pressure Requirements

There will be two different gas pressures at the gas train inlet: a static pressure which is the highest pressure in the line when there is no flow, and the dynamic pressure which is the pressure available at the inlet to the boiler gas train when firing at full rate. Sellers will design the gas train to operate at a value that is below the listed pressure, and with a maximum pressure rating that matches or is higher than the stated pressure.

If the dynamic pressure is lower than the drop allowed by Sellers, this must be identified and communicated to Sellers at the time of the sale. For example, if the building pressure regulator is a long distance from the boiler, the pressure drop in the line must be determined and stated in the order so that Sellers can design for the lower pressure that will be delivered to the boiler. If there is a large variation between the static and dynamic pressure, an additional regulator may be required to provide a more stable constant pressure.

Table 3.3 shows the gas flow capacities of 100 ft sections of straight pipe of various diameters, assuming a pressure drop of 5% along the length of the pipe. The bottom row gives capacity multipliers for other lengths. By using this table to determine flow capacity, combustion issues caused by excessive drops in dynamic pressure can be avoided.

INITIAL GAS PRESSURE	TOTAL PRESS. DROP	GAS LINE CAPAITIES (CU-FT/HR THROUGH 100 FT LENGTH)											
		DIAMETER OF PIPE IN INCHES											
		1/2	3/4	1	1-1/4	1-1/2	2	2-1/2	3	4	5	6	8
7″ wc	0.35″	31	69	139	305	475	962	1570	2860	5990	10900	17700	36300
8″ wc	0.40″	33	74	148	327	508	1030	1680	3060	6410	11700	19000	38800
9″ wc	0.45″	35	79	158	347	540	1090	1780	3250	6810	12400	20200	41200
10″ wc	0.50″	37	83	166	366	569	1150	1880	3430	7180	13100	21300	43500
11″ wc	0.55″	38	87	175	385	598	1210	1980	3600	7550	13700	22300	45700
12″ wc	0.6″	40	91	183	402	625	1280	2060	3760	7890	14300	23300	47700
1/2 psi	.025 psi	43	98	197	433	673	1360	2220	4050	8590	15400	25100	51400
3/4 psi	.038 psi	53	121	243	534	831	1680	2750	5000	10500	19100	31100	63500
1 psi	.050 psi	62	141	282	622	967	1960	3190	5820	12200	22200	36100	73800
1-1/4 psi	.062 psi	70	159	319	702	1090	2210	3600	6570	13800	25000	40800	83300
1-1/2 psi	.075 psi	77	175	351	773	1200	2440	3970	7240	15200	27600	44900	91800
1-3/4 psi	.088 psi	84	191	382	842	1310	2650	4320	7870	16500	30000	48900	99900
2 psi	.100 psi	91	205	412	906	1410	2850	4660	8480	17800	32300	52600	108000
2-1/2 psi	.125 psi	103	233	467	1030	1600	3240	5280	9620	20200	36700	59000	122000
3 psi	.150 psi	114	259	519	1140	1780	3600	5870	10700	22400	40800	66300	136000
3-1/2 psi	.175 psi	125	283	568	1250	1940	3940	6420	11700	24500	44600	72600	148000
4 psi	.200 psi	135	307	615	1350	2110	4270	6960	12700	26600	48300	78700	161000
4-1/2 psi	.225 psi	146	330	661	1460	2260	4580	7480	13600	28500	51900	84500	173000
5 psi	.250 psi	155	352	706	1550	2420	4890	7980	14500	30500	55400	90200	184000
6 psi	.300 psi	174	395	792	1740	2710	5490	8960	16300	34200	62200	101000	207000
8 psi	.400 psi	211	477	957	2110	3280	6640	10800	19700	41300	75200	122000	250000
10 psi	.500 psi	246	556	1120	2460	3820	7730	12600	23000	48200	87600	143000	292000
Multiply the capacities above with the multipliers below to obtain the capacity for a pipe length other than 100 feet.													
Length of pipe in ft		10	15	25	50	100	150	200	250	300	350	400	500
Multiplier		3.16	2.58	2	1.41	1	0.817	0.707	0.632	0.577	0.535	0.5	0.447

Table 3.3 Gas Line Flow Capacities

⚠CAUTION

IF THE ACTUAL SUPPLY PRESSURE AT THE JOB SITE IS LESS THAN THE PRESSURE STATED ON THE ORDER, THE UNIT MAY NOT MAKE CAPACITY. THE GAS TRAIN IS DESIGNED TO PASS THE VOLUME OF GAS FOR CAPACITY WITH THE PRESSURE STATED. LOWER GAS PRESSURES WILL RESULT IN LOWER RATES.

There should be some consideration for the possibility of pressures exceeding the rating of the gas train. Over-pressure protection is generally provided by dual regulators and/or safety relief valves.

⚠DANGER

THE GAS SUPPLY PRESSURE CANNOT BE ALLOWED TO EXCEED THE RATINGS OF THE BURNER GAS TRAIN COMPONENTS. FAILURE TO PROVIDE PRESSURE PROTECTION COULD CAUSE EQUIPMENT DAMAGE, PERSONAL INJURY OR DEATH.

The gas piping to the boiler must comply with all applicable code requirements and may also need to meet local gas supplier requirements as well as insurance regulations. In addition, there should be a cleanout leg on all gas lines at the point of connection to the boiler.

⚠WARNING

IF THE PIPING IS NOT PROPERLY CLEANED, DEBRIS CAN BECOME LODGED IN THE PRESSURE REDUCING VALVE AND PREVENT THE VALVE FROM WORKING. THIS CAN RESULT IN HIGH GAS PRESSURES WHICH COULD RESULT IN EXCESS GAS FLOW AND EXPLOSION, RESULTING IN DAMAGE, INJURY OR DEATH.

Make certain the main gas supply line is clean before connecting it to the boiler. Loose materials in the gas lines such as scale, welding slag, or metal chips are almost certain to cause faulty operation of gas pressure regulators and control valves. These items must be removed, and the piping should be cleaned prior to placing the boiler into service.

Teflon tape or compounds with Teflon content as a pipe sealant are not recommended. Component warranties may be voided if Teflon is used.

⚠WARNING

TEFLON TAPE OR COMPOUNDS CONTAINING TEFLON FOR PIPING SEALANT ARE NOT RECOMMENDED.

The burner gas supply lines should be located to allow full opening of the main burner assembly for normal inspection and maintenance. Provide a union in both the main burner and pilot burner gas supply lines. Locate these unions so the gas lines can be readily disconnected when it is necessary to open the main burner assembly.

When pressure testing the gas lines, the gas trains on the boiler must be isolated. The gas cocks must be closed. If any question exists as to the rating of the gas cocks relative to the required test pressure, the lines should be disconnected and blocked off to avoid damage to gas train components.

Both the main burner gas pressure regulator and the pilot burner gas pressure regulator are supplied with the boiler. These regulators have been furnished to operate with a specific gas type and inlet pressure that were defined at the time of the order. These regulators have been adjusted to provide the approximate outlet pressure when the boiler is in normal operation.

⚠WARNING

IF THE GAS SUPPLIED IS OF A DIFFERENT TYPE, OR IF THE GAS SUPPLY PRESSURE DOES NOT MATCH THAT LISTED ON THE NAMEPLATE, IT MAY CAUSE EQUIPMENT DAMAGE, PERSONAL INJURY OR DEATH.

It is important that vent lines be connected to all valves that require a vent. Boilers rated 40 through 80 HP will require the pilot regulator and vent valve to be vented. Boilers 100 HP and larger will only require that the vent valve be vented. The venting requirements can be determined from the component details for the boiler. Venting lines must be vented to the outside of the building. Vent lines should be of adequate size. The normally-open vent valve must be vented with full size piping and must be vented separately from any other control containing a diaphragm. Unions must be supplied in appropriate locations in the vent lines to allow disconnection for opening the burner door. Where local governing agencies or gas companies have established regulations regarding the venting of gas pressure regulators, those requirements should be followed. The termination points of the vent(s) should be turned down to prevent water from entering and should be protected against the entry of insects.

It should be noted that propane is generally not vented because it is heavier than air and would collect in pockets from the vent lines, creating a potential hazard.

Gas piping should be tested for leaks using soap bubbles. Shipping and handling can cause small leaks. These must be tightened prior to boiler operation.

3.5. Electrical Connection

All electrical wiring must comply with all applicable code requirements, including the National Electric Code, insurance regulations, and all local codes. Refer to the wiring diagram for this boiler for all wiring connections.

Connect the electric power supply lines to the marked wires or terminals in the junction box that is rigidly mounted on the boiler shell at the hinge. A fused line switch (safety switch) should be provided in the power supply line. This switch is not furnished with the boiler. The wire size must be adequate for the full electrical load on the boiler and the boiler must be well grounded. Any connections made to the single-phase boiler control circuit must also be made at the hinge location and allow the door to be fully opened for inspection, maintenance, and adjustments.

⚠CAUTION

ANY CONNECTIONS MADE TO THE BURNER, ELECTRICALLY OR MECHANICALLY, SHOULD NOT PREVENT THE BURNER FROM OPENING. THE BURNER MUST BE OPENED PERIODICALLY FOR INSPECTION AND MAINTENANCE.

The main power disconnect for this equipment must be conspicuously labeled and placed within sight of the operating system and equipped with lockout provisions.

The control circuit on all immersion-fired boilers is arranged for operation with a 120 V, 60 Hz, single-phase power supply. The blower motor may be either single phase or 3-phase with a voltage specified by the purchaser. When the blower motor circuit is single-phase and other than 120 V, or when it is a 3-phase circuit, a control circuit transformer is furnished to provide a 120 V, 60 Hz, single-phase power supply for the control circuit.

The pump control contacts on the pump control/primary low water cutoff must be connected to the boiler feed system if on/off control of the boiler feed pump is to be accomplished using this control. Any alternative arrangement could require different electrical arrangements. Check the job-specific engineering documents for required details.

3.6. Flue Connection

Stacks and breeches must be designed to maintain a constant draft at the boiler outlet without a large variation. The draft should be maintained at +/- 0.1” (from -0.1” to + 0.1” stack pressure measured at the outlet of the boiler). More critical than the actual pressure is the amount that it could vary at any given firing rate, which will upset the combustion fuel-air ratio, and must be no more than +/- .05” or half of the total allowed draft variation. Larger variations in draft may result in combustion noise or rumbling. It is recommended that the stack design be performed by a qualified engineering firm or manufacturer that has experience in this equipment.

The stack should be designed to avoid wind influences from adjacent structures as well as to prevent the flue products from entering inlet ducts, windows or other occupied areas. It 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 combustion gases to an undesirable location. Local codes should be checked for criteria on heights and other design codes.

The breeching should be designed to be as straight and short as is practical. Smooth bends, gradual transitions, low velocities and tight construction are all important. Round breeching is preferred to square or rectangular ducts because they are more efficient and less likely to generate noise on the flat surfaces due to resonance. The size should be based on the total flow through the breeching, with diameter changes when adding additional boilers, using smooth transitions. Also, review the information in "Firetube Boiler Engineering Manual" published by the ABMA and NFPA 4.7.8.

Normally, a boiler fitted with a single stack of the correct diameter, and which is less than 30 feet tall will not have any major draft issues. On the other hand, tall stacks, complicated breeching, adjacent tall structures, or multiple boilers connected to a single stack can cause serious draft problems and must be designed to deal with those issues to prevent the draft from exceeding the +/- 0.1" limit, and to prevent turbulence that will feed back into the combustion and result in combustion noise or rumbling. The most common and effective draft controls are barometric dampers. If another type of draft control system is used, it should include a feed forward control tied to the modulation system to prevent over- and under-shoot, especially at low loads. Any draft control system should allow other boilers to modulate and start/stop without causing an upset in the draft at other boilers. Upsets in draft can result in combustion noise or rumble, which often will not stop until that boiler is taken offline.

All flue piping to the boiler must comply with all local code requirements. Install the flue piping from the flue outlet on the boiler to the building stack, or to a separate stack. Horizontal runs of the flue piping should be avoided, and when necessary, should be as short and direct as possible and pitched upward approximately 1 inch per foot. The connection to the boiler must allow smooth exit of the gases from the boiler. Connection of the boiler exit to horizontal breechings must be accomplished using smooth angled wye connections or elbows. Tee connections will cause venting problems and must not be used. Many different brands of boiler stack are available on the market. These are often superior to the single wall, sheet metal stacks described above because of the ease of installation and double wall construction. If this material is used it should be properly sized, and the manufacturer's instructions should be followed. Flue piping is not furnished with the boiler.

⚠CAUTION

STACK DESIGNS AND DRAFT CONTOLS THAT DO NOT PROVIDE CONSISTENT DRAFT REGULATION WITHIN THE REQUIRED DRAFT RANGE OF -0.1" TO + 0.1" AND +0.05" TO -0.05" AT ANY RATE MAY CAUSE COMBUSTION NOISE AND WILL NOT BE ACCEPTABLE. SELLERS WILL NOT BE RESPONSIBLE FOR CORRECTING THESE ISSUES.

The flue gas stack and breeching are part of the combustion system, and upsets in the flow of the flue gas usually result in combustion noise in the system. To prevent this noise, always provide a smooth transition of the flue gas. Common considerations include:

- The connection of the breeching to the stack or other breeching should never use a 90-degree connection or a "T", but rather should use a 45-degree sweep angle.
- When multiple boilers are connected, increase the breeching diameter with each additional boiler, providing a 10-degree angle to connecting diameters.
- Do not align multiple breeching connections to the stack in line with each other, as they will tend to influence each other. Make the connections above or below other stack connections to prevent feedback.
- Do not use large flat surfaces, as they tend to resonate (from the inherent combustion pulsations)
- If the stack is connected directly to the vessel, do not allow rain or condensate to run back down into boiler as it will cause corrosion in the vessel.
- If barometric damper(s) are used, there cannot be a positive pressure in the stack, or the flue gases will flow out of the stack and into the boiler room.
- The connections to the stack and breeches must be tight. In addition to the stack and breeches, the relief door should be checked for a tight seal. If the gasket is damaged or is missing in some areas, it should be replaced. Air leaks in the boiler area can result in the burner being adjusted to a rich condition that can result in high CO and unburned gas when the air temperature is warmer.

⚠WARNING

FAILURE TO PROVIDE CONSISTENT STACK PRESSURES CAN RESULT IN GAS SIDE EXPLOSIONS CAUSING DAMAGE, INJURY OR DEATH. THE SYSTEM DESIGN MUST PROVIDE CONSISTENT STACK PRESSURE AT ALL TIMES, INCLUDING STARTUP, SHUTDOWN AND CYCLING OF DIFFERENT BOILERS IN A MULTI BOILER SYSTEM.

⚠ WARNING

THE STACK DESIGN MUST PROVIDE SMOOTH FLUE GAS FLOW TRANSITIONS TO PREVENT UPSETTING THE COMBUSTION PROCESS AND CAUSE COMBUSTION NOISE. FAILURE TO PROVIDE SMOOTH FLOW TRANSITIONS CAN RESULT IN EQUIPMENT DAMAGE OR INJURY.

3.7. Condensate Connection

The condensate outlet on the boiler, located on the back of the shell of the boiler behind the rear tube sheet, should be piped to a drain. Do not install a shutoff valve in any of these lines. Condensate will occur on initial startup, when the cold boiler will cause some flue gases to condense, a condition that occurs on all cold boiler startups. It may also provide a drain for rain and condensate when it occurs in the stack and can flow into the vessel. If this water is not removed, it will cause serious corrosion in the vessel.

4. WATERSIDE CARE AND REQUIREMENTS

4.1. General

Waterside care is critical to the safety and longevity of the boiler. While this chapter will cover some of the important basics of water care and treatment, it is a complex subject, and the owner should contact water treatment specialists to ensure this is being handled properly. There are several key issues that need to be addressed, including the initial cleanout, water treatment (mechanical and chemical), testing and inspection to monitor effectiveness, and frequent blowdown to remove accumulated sludge and impurities.

Feedwater equipment should be checked and ready for use. All valves, piping, boiler feed pumps, and receivers should be installed in accordance with prevailing codes and practices. Water requirements for steam and boilers are essential to boiler life and length of service. Special care must be taken when placing the boiler into initial service. The waterside of a new boiler and new or modified steam or systems may contain oil, grease, or other foreign matter and require a boil-out to remove these impurities.

Boilers also require proper feedwater supply for steam systems. Normally, the feedwater supply rate should be 50% higher than the maximum evaporation rate of the boiler when on/off feed controls are used, and slightly smaller rates for modulating feedwater controls.

4.2. Feedwater Requirements

Feedwater to the boiler is normally provided by a feed pump, which is connected to a deaerator or heated storage tank. The deaerator or heated storage tank drives off dissolved gases which would cause corrosion and shorten the life of the boiler. The condensate return is often collected in these tanks, and act as accumulators since the condensate flow can be greater than the feedwater flow. Chemicals that are required for water treatment should also be added to the deaerator or heated storage tank rather than the boiler, to improve mixing.

The feedwater pump is controlled by the LWCO, and cycles on and off to maintain the water level in the boiler. In some cases, the pump runs continuously, and a modulating control valve in the feedwater line is used to maintain the water level.

The feedwater pump of an on-off system should be sized to provide at least 50% more flow than the maximum capacity of the boiler. A modulating feedwater control system can use a slightly lower flow rate.

Before operating a pump on a steam boiler, make sure all the valves in the feed line are open to prevent damage to the pump. Also check the rotation of the pump and correct the rotation if required. If this is an on/off water level control system, the pump should cycle off when the proper water level is obtained. If this is a modulating level control, the water flow rate will decrease as the proper water level is reached.

4.3. Water Treatment

A good water treatment plan is critical for the long-term life, cost, and safety of the boiler. The following criteria should be included in any plan:

- Preventing scale buildup or deposits, which can reduce heat transfer and cause overheating of the metal surfaces.
- Eliminate corrosive gases in the supply or boiler water.
- Prevent intercrystalline cracking or caustic embrittlement of the boiler metal.
- Prevent carryover and foaming.

Generally, several different techniques are used to accomplish these goals, including pre-treatment, chemical treatment, and blowdown. Pre-treatment can include filtering, softening, deaerating, and other treatments depending on the actual feedwater makeup. Surface and/or bottom blowdown are typically used with steam boilers, to remove the solids left behind from the evaporation process.

The internals or waterside of the pressure vessel should be inspected periodically to ensure that there is no buildup of scale or deposits. The frequency of the inspections should start more frequently but can be reduced depending on the findings. Most states have formal requirements for this activity.

Sellers recommends that a water specialist be contacted to develop a plan for water treatment that is tailored to the local water conditions and the operation of the boiler. The plan should include testing to determine the effectiveness of the treatment plan and how modification should be made to correct problems.

⚠CAUTION

FAILURE TO DEVELOP AND FOLLOW A WATER TREATMENT PLAN WILL RESULT IN PREMATURE VESSEL FAILURE.

4.3.1. Boiler pH

Natural water is usually between 6.5 and 7.5 ph. A common recommendation is to maintain boiler water at 10 ph.

Acidic water is corrosive. Alkaline water is more prone to scaling.

Alkalinity is a measure of the bicarbonate (HCO_3), carbonate (CO_3) and hydroxyl (OH) ions in the water. pH and alkalinity ratings are NOT the same and are NOT proportional. pH is rated on the pH scale and the alkalinity rating is measured in parts per million (ppm). A typical recommended alkalinity rating is 140 – 700 ppm for boilers operating below 300 psi.

4.3.2. Controlling pH

pH is controlled by either removing water impurities or adding other chemicals to neutralize the condition. For example, caustic soda (NaOH), an alkaline, is added to neutralize H_2CO_3, carbonic acid.

4.3.3. Acid Attack

When the boiler water pH drops below about 8.5, a corrosion called acid attack can occur. The effect exhibits rough pitted surfaces. The presence of iron oxide deposits on boiler surfaces can encourage this kind of corrosion. A low boiler water pH is usually caused by contamination of the boiler feed water, from sources such as hydrochloric or sulfuric acid from leaks in demineralizers and condenser leaks of cooling tower water. Contamination can also occur from process leaks of acid or acid-forming materials into the return condensate system.

4.3.4. Caustic Attack

Caustic attack on boilers is a localized attack due to extremely high pH (12.9 or higher). It can take two forms: caustic gouging or caustic cracking, also called caustic embrittlement. Caustic attack or caustic corrosion is often encountered in phosphate treated boilers in which deposits of phosphates or other scale occur in high heat transfer areas. Boiler water can permeate the porous deposit resulting in localized corrosion. When it is coupled with significant heat flux, concentration of the boiler water occurs rapidly, speeding the corrosion.

The corrosion action is a result of the formation of caustic-ferritic compounds through the dissolving of the protective magnetite film. Once the process begins, the iron in contact with the boiler water will attempt to restore the protective magnetite film. Caustic corrosion (typically in the form of gouging) continues until the deposit is removed or the caustic concentration is reduced to normal.

Caustic soda (NaOH) is the only normal boiler water constituent that has high solubility and does not crystallize under typical boiler conditions. Its caustic concentration can be as high as 10,000-100,000 ppm.

Careful control of boiler water chemistry can prevent caustic gouging. If the free hydroxide alkalinity is set too high or uncontrolled, then caustic gouging may result. Prevention of porous deposit formation (such as iron oxide) eliminates a place for caustic gouging to occur.

4.3.5. Suggested Water Quality Limits

BOILER TYPE: Industrial fire-tube, high duty, primary fuel fired.

MAKEUP WATER PERCENTAGE: Up to 100% of feedwater

CONDITIONS: No superheaters, turbine drives, or process restrictions on steam

SATURATED STEAM PURITY TARGET: 1.0 ppm TDS in the steam

Drum Operating Pressure (PSIG)	0-300
Feedwater	
Dissolved Oxygen before scavenger feed (mg/L O)	<0.04
Dissolved Oxygen after scavenger feed	<0.007
Total iron (mg/L Fe)	<0.1
Total copper (mg/L Cu)	<0.05
Total hardness (mg/L $CaCO_3$)	<1.0
pH range @ 25°F	9.0-10.5
Nonvolatile TOC (mg/L C)	<10
Oily matter (mg/L)	<1
Boiler Water	
Silica (mg/L SiO_2)	<150
Total Alkalinity (mg/l $CaCO_3$)	<700
Free Hydroxide alkalinity (mg/l $CaCO_3$)	Not specified
Un-neutralized conductivity (µS/cm @ 25°F)	<7000

Source: The American Society of Mechanical Engineers

A comprehensive mechanical and chemical treatment system should ensure many years of service from your steam system.

4.4. Thermal Shock

All Sellers immersion fire-tube boilers have a single-pass design that provides uniform expansion in each tube, and no resulting thermal shock. There are no special operating or warmup requirements for the Sellers immersion fire-tube boiler. The unit can be started and immediately driven to high fire (Sellers has been doing this for over 50 years).

4.5. Cleaning

Steam piping systems connected to the boiler may contain oil, grease or foreign matter that is harmful to the boiler. These contaminates must be cleaned to prevent damage to the vessel and control valves. On a steam system, the condensate should be dumped until it is clear of these impurities.

The pressure vessel must be kept clean from oil, grease, sludge and foreign material. These impurities can prevent the boiler from operating properly, and cause water carryover, poor efficiency, and overheating of the vessel components in severe cases. If these impurities are present, the boiler internals may need to be cleaned. Cleaning is also recommended during the initial installation and startup process. In some cases, impurities from the system or condensate can be carried into the vessel, even if the vessel was properly cleaned.

A boil-out of the vessel interior is required on a new boiler startup to remove oil, grease and other impurities that could be left from the construction and installation process. This requires that the boiler be operated at low rates to warm the vessel up for the proper cleaning action. The operator must be prepared for this, and fully versed in the unit startup, which is described in later chapters. There are several different methods and chemicals that can be used for the boil-out process, and the detailed instructions for the chemicals used should be followed. Some general guidelines would include:

- Refer to Table 3.1 for the flooded water capacities (in gallons), which should be used to determine the quantity of chemicals needed.
- The relief valves should be removed from the boiler to protect them from the chemicals.
- An overflow pipe should be attached to one of the boilers' outlets and routed to a safe point of discharge. Often the safety valve or relief valve connection is used.
- All valves leading to or from the vessel should be closed to protect the system from the chemicals.
- The boiler should be fired intermittently to warm it up, allowing for a more uniform temperature.
- Remove the handhole plates and wash the waterside of the vessel until the drain water appears clean.
- Disposal of the chemically treated boil-out water must be considered. Check local requirements in advance of the boil-out.
- After completing the boil-out, fill the boiler with fresh water, and fire the boiler to at least 180 °F to drive off any gases from the fresh fill water. Dump the condensate until it can be verified to be clean.
- Pay special attention to the fresh makeup water treatment during this time, because you will be using a large quantity of makeup water, even more than the system was designed to handle.

⚠ WARNING

ONLY PROPERLY TRAINED AND EXPERIENCED SERVICE TECHICIANS SHOULD PERFORM THESE OPERATIONS. FAILURE TO PROPERLY HANDLE THE CHEMICALS OR PROPERLY START THE BURNER CAN CAUSE SERIOUS INJURY OR DEATH.

A steam boiler should be inspected three months after being placed into service, and thereafter as warranted by the conditions. Any sign of corrosion, pitting, sludge or other buildup is an indication that the water treatment program needs to be changed to deal with the identified problem. Each boiler application is unique due to the specific makeup of the raw water, the process used to treat the water, and the boiler application.

4.6. Blowdown

Boiler blowdown is a process of removing solids, sludge and boiler water with high concentrations of impurities. The boiling action of a steam boiler will leave the impurities of the feed water behind, and they will be concentrated in the vessel. If left alone, the boiler would fill with solids and sludge to a point where the bottom rows of tubes would be covered and overheated because they are no longer cooled by the water.

Solids are brought in by the feedwater. No amount of treatment can remove all the solids, and these solids will build up in the vessel. Solids become less soluble in the higher temperatures of the boiler and tend to accumulate on the heated surfaces. Therefore, chemical treatment and blowdown are required to remove these solids to prevent them from forming harmful scale and sludge. Scale buildup on heating surfaces can act as an insulator reducing boiler efficiency and more importantly, cause the metal to overheat and fail.

⚠ WARNING

FAILURE TO PROVIDE ADEQUATE WATER TREATMENT AND SOLIDS REMOVABLE CAN RESULT IN METAL OVERHEATING AND FAILURE, CAUSING SERIOUS INJURY OR DEATH.

There are two primary means of blowdown: an intermittent manual blowdown from the bottom of the boiler and continuous blowdown from the surface of the water in the boiler. In addition to the vessel, blowdown may also be required for the water columns.

Bottom blowdown is required in all applications. The blowdown tapping is located at the bottom of the boiler. The blowdown piping for high pressure boilers includes two valves, a slow opening and fast opening valve. Low pressure boilers have a single valve in the blowdown piping. The bottom blowdown is used to remove solids and sludge that collects on the bottom of the boiler. This process is performed periodically, often once per shift. If there is little condensate return and more solids in the feedwater, this may be more frequent and for longer durations. Likewise, with a high percentage of condensate return and cleaner feedwater the blowdown frequency and duration of the blowdown can be reduced.

The best time to perform the bottom blowdown cycle is when the boiler is operating at low loads. Normally, the quick opening valve is opened, and the slow opening valve is slowly opened and closed to provide the blowdown. The timing of the process should be defined based on test results of the process. If done too quickly, the vessel will not be properly cleaned, and will continue to build up. If the process is too long, energy and water will be wasted. Again, frequent water quality tests should be used to determine the duration of the blowdown cycle, and adjustments made to keep the solids in the desired range.

Continuous blowdown is done to the water surface and used to remove oils and impurities that accumulate on the water surface. A skimmer pipe is used inside the boiler, where numerous small holes across its length are used to collect water across the diameter of the boiler (the skimmer pipe is provided as a standard on all high-pressure boilers). A needle valve is used to provide flow control, for a continuous surface blowdown. This line must be piped to a safe point of discharge and is often tied to the same blowdown system as the other equipment, to provide cooling and energy recovery.

4.7. Periodic Inspections

Insurance regulations and local laws will require periodic inspections of the pressure vessel by an authorized inspector. Normally, each state has jurisdiction over boilers, and has different requirements. Depending on the type of inspection, the vessel may need to be opened for inspection, with the water drained out and the handhole and manhole covers removed. They may also require the front and rear doors to be opened and water columns opened. The authorized inspectors will be checking the pressure vessel to ensure that it is safe to operate, and that no damage has occurred.

This is a good time to inspect the water columns for free and smooth operation and replace any parts showing wear or distortion. The bowl should be checked for any solids buildup and cleaned if required. Also check the column piping to be sure it is clean, removing the pipe plugs and pushing a rod through the piping to make sure they are clear. Proper water level maintenance is one of the most critical safety issues with a boiler, and these controls are the only means of providing that safety.

The fireside of the vessel should also be cleaned if needed. Dirt and soot accumulation can result in higher stack temperatures which will reduce the boiler efficiency. This is also a good time to inspect the vessel metal, joints, weldments, tubes and other components.

Prior to performing an inspection, new gaskets for the handholes, manway, front and rear doors, water columns and other inspection points should be obtained.

4.8. Preparation for Extended Lay-Up

Boilers that will be offline for an extended period can be put into either dry or wet storage. There is no simple rule for which type is best, but some specific factors may help determine which to use. Special attention should be given to idle boilers so that the fireside or waterside surfaces do not deteriorate from corrosion.

The dry method is best for very long-term storage or if there is the potential for freezing. In this method, the water is drained out of the boiler, then the vessel is cleaned and dried. A moisture-absorbing material is placed in trays inside the vessel (about 2 to 3 pounds of quick lime per cubic feet of space, or 1 pound of silica gel for each 6 cubic feet of space). Fireside surfaces may be coated with an anticorrosive material. All openings to the vessel, including handholes and manholes, must be sealed off. Feedwater and steam connections must be sealed off. Damper and vents should be closed to prevent air from reaching the fireside surfaces. Period inspections should be done to check the condition of the boiler and replace the moisture absorbing material.

For wet storage, the vessel is flooded with water for storage. All the fireside surfaces should be cleaned, and protective coverings can be used if longer storage periods are expected. The water in the vessel must either be properly treated or heated (to 180 °F) to remove dissolved gases. Chemicals may also be added to the water to prevent corrosion. The vessel should be pressurized with nitrogen, as an open vessel would attract oxygen and corrosion.

If the unit is being stored in a humid location, the power should be left on to keep the control panel warm to prevent condensation. Also, the control panel could be removed and stored in a dry location.

Locations with high humidity may require other methods to prevent corrosion.

5. SEQUENCE OF OPERATION

The flame safeguard provides the safety sequence of the burner, by checking various interlock switches at critical points in the sequence, and by providing very specific startup and shutdown procedures. A user manual for the flame safeguard is included in the information provided by Sellers. The following sections describe the sequence of operation for the Siemens flame safeguard. Other controls may have slight differences in timing and adjustments.

5.1. Pre-Purge Cycle

At the initial startup of the burner, the unit will go through a pre-purge period that lasts approximately 90 seconds. This cycle uses the fan to blow air through the burner, combustion zone, and vessel to clear any combustible gases that may have collected there. While the fan is running, the air damper is also opened to increase the air flow rate.

a. The following switches or controls must be closed (contacts made) to complete this cycle:
   - Low water cutoff(s) (sufficient water is in the boiler)
   - Manual on/off switch in “ON” position
   - Low gas pressure switch
   - High gas pressure switch
   - High limit steam pressure control

b. The call for heat light on the control panel is illuminated.

c. Main gas valve proof of closure switch (if provided) must be closed (contacts made.)

d. The blower motor starter is energized from the flame safeguard control and the blower starts.

e. The air flow proving switch must close (contacts made).

f. The blower runs and purges burner and boiler with air for about 90 seconds.

g. The air damper modulates to high fire (as determined by position), and depending on the programming, must remain there for a period of time before modulating to the ignition point.

5.2. Pilot Trial for Ignition

Once the purge cycle is complete, the burner will go through a cycle to ignite the pilot, and prove that it is lit, which takes between 7 to 10 seconds.

a. All the above switches and controls are still closed (contacts made).

b. The pilot gas valve and the ignition transformer are energized from flame safeguard control.

c. The ignition transformer and electrode produce a spark at the top pilot tube. Pilot gas is partially mixed with air in the pilot assembly, and then this mixture is ignited starting at the ignition electrode. The flames spread and travel (flash) down and across pilot runners. The pilot flame engulfs the pilot flame proving electrode at the bottom of the pilot assembly on the perpendicular proving leg at the end of the bottom pilot tube.

d. The pilot flame proving electrode proves the presence of a pilot, in the proper location, to the flame safeguard control.

e. If the pilot proving electrode (flame rod) does not register a pilot flame within 10 seconds, the flame safeguard will shut down the burner and indicate a pilot failure.

5.3. Main Flame Trial for Ignition

Once the pilot has been proven, the control will go through a main flame startup, which will last about 7 seconds.

a. The pilot has been ignited and proved.

b. Main burner indicator light is illuminated.

c. Main burner gas valve(s) and the normally open vent valve (if furnished) are energized from the flame safeguard control.

d. Gas flows to the proportioning mixer and mixes thoroughly with the combustion air. This mixture exits the main burner nozzles, crossing the pilot flames, and is ignited.

e. If the boiler is 50 horsepower or smaller, the control will allow a delay for the main flame ignition, then look for a signal from the flame rod. If the electrode proves a flame is present, the cycle is complete. If there is no flame signal, the burner will shut down and indicate a flame failure.

f. If the boiler is 60 horsepower or above, the flame rod switching relay will be energized and the control will look for the main flame rod to prove a flame is present. If the main flame proving electrode proves the presence of the main burner flame to the flame safeguard control through the flame safeguard, the cycle is complete. If the flame rod is not energized by the main flame within the trial period, the flame safeguard will cause a shutdown and indicate a flame failure.

5.4. Run Period

Figure 5.1 shows the operating cycle from a cold start. The cycle begins when the boiler is powered, and the burner is enabled. This means that all safety conditions have been met. Light-off starts at the ignition point, then modulates up to high fire. If the steam pressure is greater than the boiler set point, the firing rate will drop off. The PID control uses the steam pressure to determine how to operate the burner in response to the load demand. Likewise, if the steam pressure is less than the boiler set point, the firing rate will increase. If the operating pressure continues to rise due to insufficient demand, the firing rate will drop to low fire. The burner will eventually shut off if the operating temperature continues to rise beyond this. If for some reason the burner fails to shut off and the pressure continues to rise beyond the shut off point, the high limit will disable and shut the burner off. In the flame safeguard, the operating and modulating pressures are adjustable settings, and the control compares these to actual pressures from the steam pressure sensor on the vessel.

5.5. Post Purge Period

When the burner cycles off, it will go through another purge cycle to remove combustible gases from the combustion chamber. This is a much shorter cycle than the pre-purge but can be adjusted.

a. The operating PID control causes the burner to cycle off, and all gas valves and the ignition transformer are de-energized. All indicating lights are out.

b. The blower motor runs for 45 seconds then shuts off.

c. The boiler is in standby waiting for the next call for heat.

d. The flame safeguard control also will shut off the burner and initiate a post purge on the trip of any safety device.

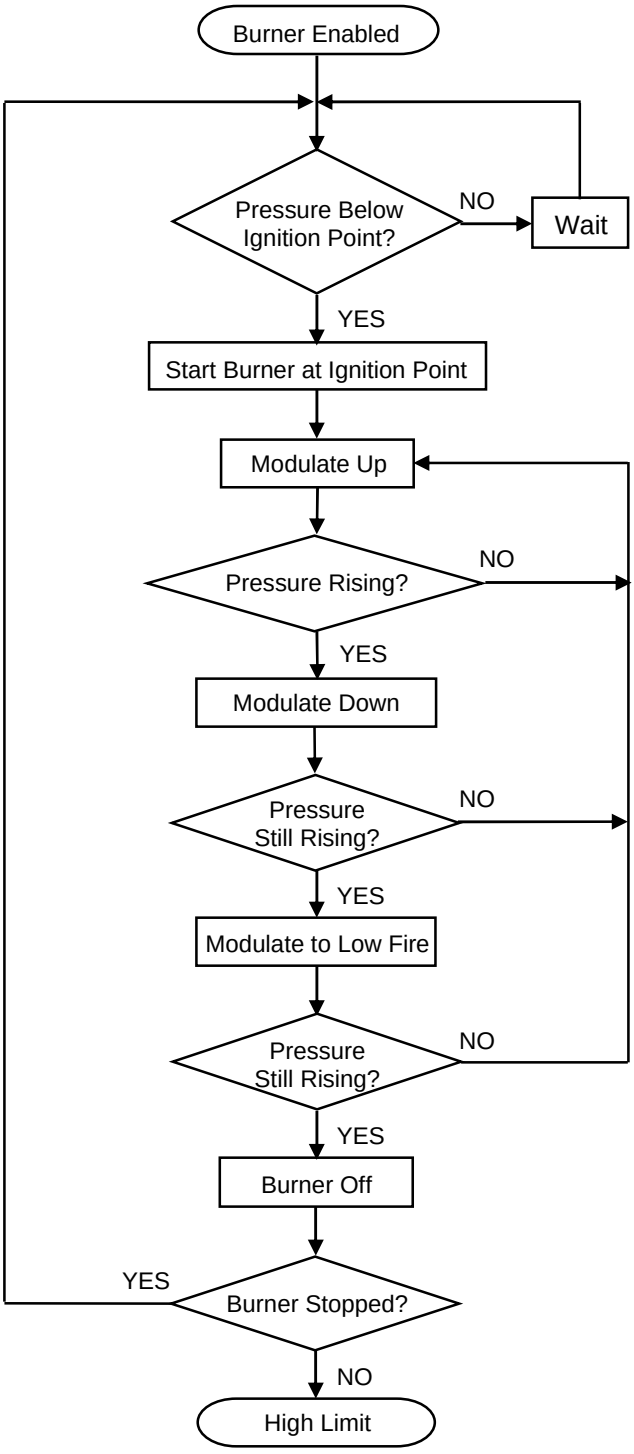


Figure 5.1 Modulating Control

6. PREPARING FOR OPERATION

6.1. General Inspection

During a new boiler start-up, the boiler will have initial settings which will support the startup process. These settings include the primary air, secondary air, pilot gas pressure, main gas pressure, and a fuel curve with the fuel and air settings from low- to high-fire. These adjustments should be left undisturbed for the initial start-up of the boiler. These settings are listed in the factory fire test report, and a copy of this report should be readily available to help with the startup process. The data listed on the factory fire test report was recorded with the boiler firing. The blower pressure, manifold pressure, and combustion chamber pressure will not match the factory readings unless the main burners are on and stable. It should be remembered that the actual pressures will vary, especially at different air temperatures and elevations (the factory test is done at 950 feet)

When restarting an existing unit that has been moved, modified, or otherwise changed, additional setup work will be required to determine the proper settings. If the initial setup data is available, that data can be used to help set up the equipment. Remember that if components have been changed, they may not (and probably will not) follow the same settings as the original components.

The first step is to make sure the complete system is ready for operation, including the feedwater, electrical, fuel supply, breeching and stack, control, and steam systems. Proper operation of the boiler may require that some steam be dumped to allow the boiler to fire at full rate. Consideration may need to be given to the feed system if it is not capable of handling a low condensate return rate during this period.

Prior to burner startup, contact the local gas company to determine if any correction factors must be applied to their indicated flow rates. This information is important as it relates to achieving specific BTU/hr. input rates.

6.1.1. System Inspection and Preparation

When preparing and inspecting the system, be sure of the following:

a. The feedwater/system pump and related piping and controls are connected and operational.

b. There is sufficient load to operate the boiler at full rate. **A steam vent will be required to allow the boiler to operate for a sufficient time to make combustion adjustments. Failure to supply an adequate to will prevent proper setup of the boiler and result in additional startup cost.**

c. There is sufficient water to support the operation of the boiler, including operation at full rated capacity.

d. The stack and breeching are connected to the boiler.

e. The breeching and stack are designed and installed according to the guidelines of Section 3

f. When using a tall stack (over 30 feet), or when multiple boilers are connected to a common stack, there is a draft control system that will maintain the required draft.

g. The fuel lines have been cleaned, especially if they are new lines.

h. The fuel supply pressure matches the stated gas supply pressure and cannot exceed the rating of the fuel train components or the stated pressure for which the gas train was designed.

i. A pressure gauge is installed on the gas supply line to the burner upstream of the main gas pressure regulator. The gauge should have a range that is twice the expected supply pressure. Make sure all main manual valves are closed before installation. Slowly open the manual main gas valve while monitoring the gas pressure. If the pressure does not match the stated supply pressure, contact the installing party to resolve the problem.

j. There is sufficient fuel supply and pressure to operate all the users, and the supply pressure matches the pressure listed on the Sellers order information.

k. The fuel lines have been purged of air with fuel. Disconnect the pilot line at the inlet to the pilot gas pressure regulator and purge air from the gas line. Purging of the gas lines must be done in accordance with NFPA 54, the National Fuel Gas Code. After the air is purged from the gas supply line, close the manual pilot valve and reconnect the line. Leave the manual pilot valve closed.

l. The fuel lines have been checked for leaks. Usually this is done by brushing soap water on all joints while the gas train is under pressure. Leaks will show up as bubbles.

m. There is a source of combustion air for the burner.

n. The electrical supply is properly connected, and proper voltage and current characteristics are being supplied.

o. All electric switches are in the OFF position.

p. The rear relief door gasket has been checked for a tight seal. The gasket should be in good condition and provide a continuous seal.

6.1.2. Vessel Inspection

When inspecting the pressure vessel, be sure of the following:

a. The boiler and new piping should be cleaned with the appropriate boil-out procedures.

b. Check all boiler connections and all handhole and manhole openings for possible leaks. Correct any leaks.

c. Ensure all handhole and manhole covers are in place with new gaskets (after boil-out) and tightened.

d. Ensure all unused openings are capped off.

e. Ensure the safety valves are installed and piped to a safe discharge location.

f. Ensure the steam line is connected to the steam system with appropriate valves.

g. Ensure the water columns are in place and have been checked for proper operation.

6.1.3. Burner Inspection and Preparation

When preparing and inspecting the burner, be sure of the following:

a. Make sure the electrical power is turned off.

b. Check all screw-type electrical terminal connections in the boiler control cabinet for proper torque. Such terminals can loosen during shipment and a careful check will help to avoid unnecessary trouble during initial start-up operations.

c. Check rotation of combustion air fan motor. The rotation is marked with an arrow on the burner face. Normally, the motor is started momentarily using the contactor, and the direction is observed as the motor slows down. If the motor is rotating in the wrong direction, reverse the wiring leads.

d. Close all manual gas valves.

e. Prepare pressure test points for measurement. This should include adding connections and/or gauges to measure the main regulated gas pressure, the pilot regulated gas pressure, the fan pressure, manifold pressure and combustion chamber pressure. Refer to the Sellers Factory Fire Test Report for expected pressures and selection of manometers and gauges.

6.2. Burner Adjustments

In preparation for operating the unit, several checks should be done to verify the correct positions of certain items, to ensure that they did not move as a result of shipping or rigging into position.

6.2.1. Ignition Electrode

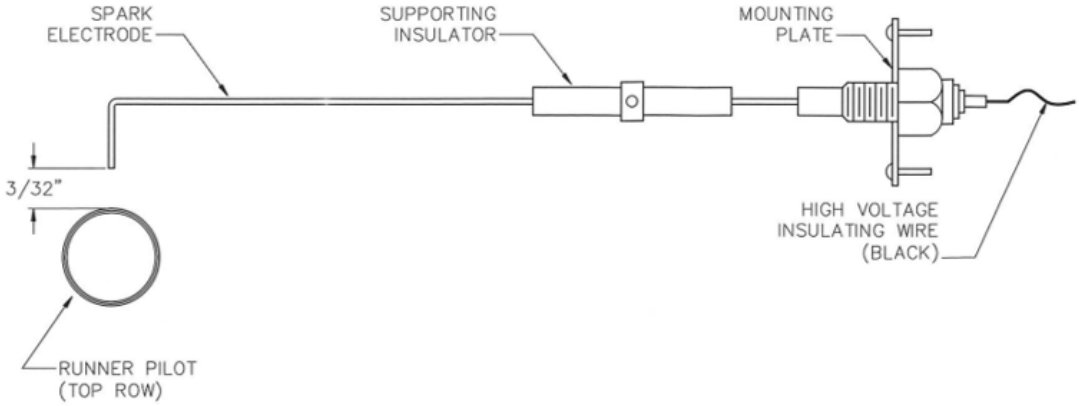


Figure 6.1 Spark Rod

The end of the ignition electrode should be positioned directly over the runner pilot ports between two of the main burner nozzles. The gap between the end of the electrode and the pilot is called the spark gap. This spark gap should be 3/32” minimum to 1/8” maximum. Improper spark gap is the leading cause of nuisance flame failures.

6.2.2. Pilot Assembly and Flame Rod

The runner pilot assembly has a flame proving leg attached to the bottom pilot tube. This proving leg extends back perpendicularly toward the burner manifold. The flame rod, or flame proving electrode should be positioned directly over the drilled flame ports of this runner pilot proving leg. The flame rod should be 3/8” minimum and 1/2” maximum above the pilot proving leg. Positioning the flame rod too close or too far from the pilot proving leg can cause nuisance flame failures. If these electrodes are not in a proper position, they can usually be correctly repositioned by opening the burner door and bending the rod slightly to the desired position. Make sure the electric power is off when checking the flame rods as they have a high voltage electrical supply.

The pilot assembly is made up of several “runner pilot” pipes which have small holes in the top that allow the gas to escape and provides a ribbon of flame in front of each nozzle. The pilot is a pre-mix style and has an air inducer fitting that allows some air into the gas stream ahead of the runner pilots. In addition to the horizontal pilot pipes, there are vertical flashers that will provide a flame path between each of the horizontal pilot pipes. The pilot flame rod is in the opposite corner from the igniter and proves that all the horizontal and vertical pilot runs are functional, allowing the flame to reach across the burner face.

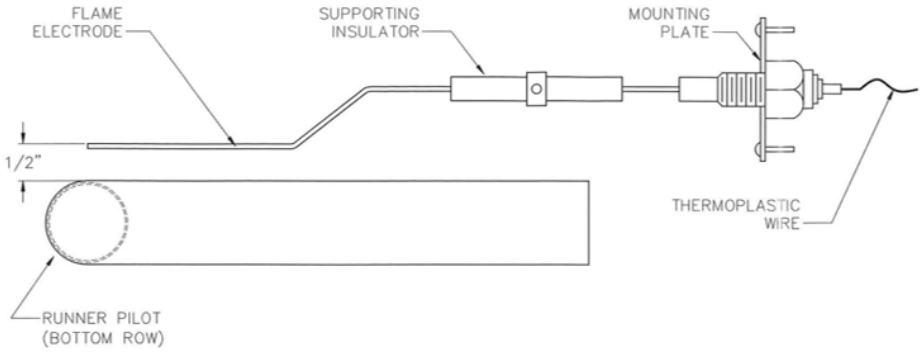
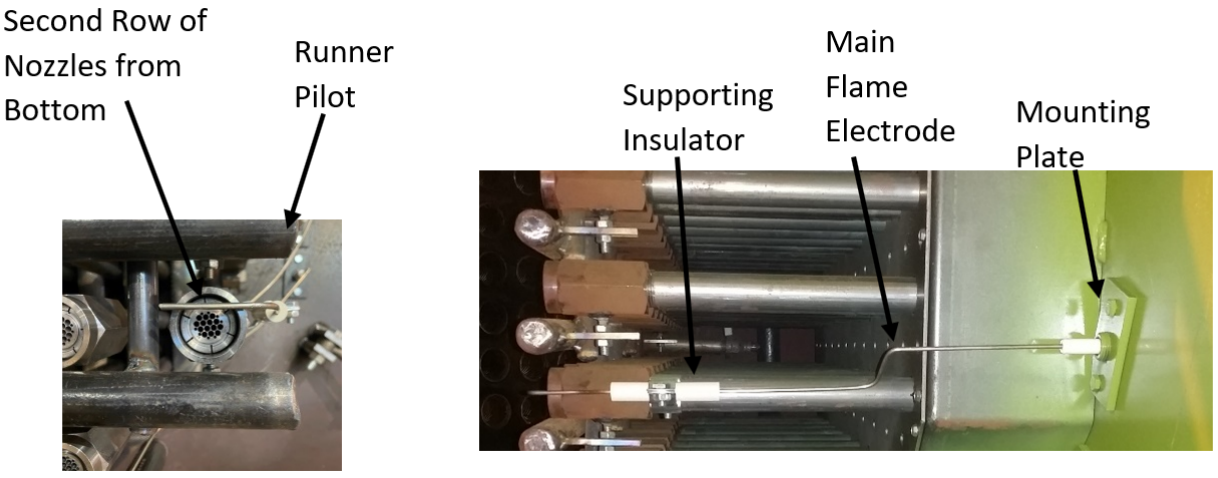


Figure 6.2 Pilot Flame Rod

6.2.3. Nozzle Flame Rod

The main flame rod is located in front of one of the main nozzles, centered across the face of the nozzle and ½" from the nozzle.



The flame proving electrodes are powered when the boiler control circuit is powered. To avoid electrical shock, be certain that the power is OFF prior to adjusting the electrodes.

6.2.4. Front Door Gasket Seal

The gasket on the front door must be checked for a tight seal. The gasket is held in place with a clamping ring, and the ring may need to be positioned closer to the door to get a good seal. The gasket should be compressed against the door, so that it will seal the gases in the furnace. If the gasket is not compressed against the door, move the clamping ring closer to the door by simply tapping it towards the door.

6.2.5. Combustion Settings

When performing the initial startup of a new unit from Sellers, the settings made at the factory during the fire-test should be adequate to begin the startup process. This does not mean that a complete startup sequence is not required, or that the combustion settings do not need to be verified and/or adjusted. Each location has different fuel properties, air density, and stack conditions which will alter the combustion and safety control settings. Also, the specific operating conditions, like modulating pressure ranges and on/off cycling points will need to be set for that specific job site.

If the unit is located at a very high elevation, adjustments are necessary before the unit will operate. In this situation, the air pressure from the fan will be lower, and the combustion air pressure switch will need a lower setting. Likewise, the gas pressures will need to be higher to overcome the low barometric pressure. The Sellers factory is located at an elevation of about 950 feet. Some changes in pressure settings may become necessary at around 1500 feet, which become more significant as the elevation increases.

⚠ WARNING

ALL BOILERS REQUIRE A COMPLETE STARTUP WHEN INSTALLED. INSPECTIONS ARE REQUIRED TO ENSURE THAT THE OPERATING CONTROLS AND SAFETY CONTROLS HAVE NOT BEEN DAMAGED IN SHIPMENT OR INSTALLATION AND THAT THEY ARE FUNCTIONING CORRECTLY AND ADJUSTED TO LOCAL CONDITIONS. COMBUSTION MUST ALSO BE ADJUSTED TO LOCAL CONDITIONS. FAILURE TO PERFORM A COMPLETE STARTUP MAY RESULT IN EQUIPMENT FAILURES, PERSONAL INJURY OR DEATH.

The initial positions of the air damper and fuel valve are normally set by Sellers Manufacturing when the unit is fire tested and should be adequate to perform the initial startup process. The air and fuel valves should be checked to show they are in a lower firing position for light-off.

⚠CAUTION

THE BURNER IS NORMALLY ADJUSTED TO START AT A RATE OF 30% - 50%. ATTEMPTING TO START THE BOILER OUTSIDE THIS RANGE MAY CAUSE PILOT FAILURES.

Monitor the pilot when it is at the desired light off position and determine where the flame rod should be located to detect the pilot at that rate. Readjust as required (see Figure 6.2).

Monitor the operation of the fuel valve and air damper as they are driven from low to high fire. Their operation should be smooth with no jerks or sudden movements. If they are not operating smoothly, check for binding or misalignment.

The secondary air settings are set at the factory. Changes may be required due to higher elevations. The secondary air position is determined by making small changes and observing the result to determine whether or not combustion has improved. There is usually a wide range of settings that will provide good combustion, but this range may be different at high and low firing rates. This adjustment becomes more critical as turndowns increase or if the unit is operating at low NOx. The best performance for a low NOx setting is achieved when the secondary air is set to a minimum position, so that more air is used to cool the flame.

6.3. Controls and Safety Check

The initial setup done by Sellers during the factory fire-test should provide a base from which to begin the startup process. There are several control settings that may need to be adjusted to meet the specific needs of your job site. Sellers does not attempt to cover all the application details in the fire-test and is primarily concerned with checking the proper operation of the unit.

In addition, there may be other controls added at the job site that are not part of the boiler equipment. It is expected that the job site startup will cover all these issues in concert with the requirements of the customer and local conditions.

Prior to startup, it is essential that all safety and operating controls be checked. The primary source of information on these controls comes from the instruction sheets from the manufacturer of the control, which are included in the boiler manual. The following general guidelines are given to provide a general process of checking the controls.

6.3.1. Primary Low Water Cutoff (Float Type)

Check the controls for smooth and free operation, as well as matching the positions for pump control and LWCO function, to make sure they were not damaged in shipping or rigging.

6.3.2. Auxiliary Low Water Cutoff (Float Type)

Check the controls for smooth and free operation, as well as matching the position for ALWCO function, to make sure they were not damaged in shipping or rigging.

6.3.3. Boiler Feed Pump Control

The feed system should be checked for proper operation prior to starting the unit. The best way to check the operation of this control is to drop the water level in the boiler to a level that is below the normal operating water level and see if the system returns the water level to the correct position.

6.3.4. Air Flow Proving Switch

The initial setting for this switch was used during factory test firing. This setting should be adjusted before start-up to match the environment where the unit is being installed. After tuning the boiler, this switch should be properly adjusted to match the final burner settings.

6.3.5. High Gas Pressure Switch

After fire testing, this is set to a point that does not allow the unit to turn on for safety. This setting should be adjusted before startup to match the environment where the unit is being installed. Once the gas pressures and combustion are set, this switch should be adjusted to slightly above the high fire gas pressure.

6.3.6. High Limit Steam Pressure Control

The high limit should be set to about 10 psi above the operating pressure.

6.3.7. Flame Safeguard

The boiler is equipped with a Siemens LMV5 parallel positioning control and a pressure sensor which are used to match the system load. If the system load remains within the modulation range of the burner, the burner will remain on and modulate as needed. If the system load falls below the modulating range of the burner, the burner will turn off, and will restart when the system load rises. The initial settings for this process should be programmed into the control before startup.

6.3.8. Low Gas Pressure Switch

After fire-testing, this is set to a point that does not allow the unit to turn on for safety. This setting should be adjusted before startup to match the environment where the unit is being installed. Once the gas pressures and combustion are set, this switch should be adjusted to slightly below the low fire gas pressure.

6.4. External Controls and Building Management Systems (BMS)

Building management systems (BMS), energy management systems (EMS), process control, and other types of communications networks can be connected to the boiler for outside monitoring and control. Sellers recommends that all outside communications to the unit be disconnected for the initial startup process. This is recommended due to any number of conditions.

Sellers can provide a communications gateway within the electrical enclosure.

Connecting a communication network to this unit in any location other than the one provided may cause issues that are outside the scope of Sellers' responsibilities. Regardless of how you interface with Sellers's equipment, always remember that the equipment and facility owner is solely responsible for the proper and safe operation of any equipment. Hire a qualified contractor to properly maintain, troubleshoot, and prepare for required inspections of your equipment, as every installation and application is unique to the site. Sellers authorize communications connections only to the provided Ethernet or serial ports. Never interfere with any factory wiring or controls, which is in conformance to applicable codes and integral to the safe operation of the equipment.

6.5. Energy Extractors

Stainless steel energy extractors are installed in each boiler tube at the factory. Check to make certain they are flush with the rear (exhaust) end of the boiler tube. The heat extractors can shift out of the boiler tubes during shipment. To restore the heat extractors to the proper position, push them forward into the boiler tube until flush with the tube end. This will ensure maximum efficiency during operation.

7. COMBUSTION ADJUSTMENTS

Combustion in a Sellers Immersion Boiler is much different than combustion in a typical boiler. This is because combustion occurs across many small burner nozzles which fire into the individual 2" tubes of the fire-tube boiler. In most boilers, combustion occurs in a large furnace and then the heat is forced through multiple passes of boiler tubes. Firing into individual tubes requires some different combustion settings and considerations, which are outlined below.

Figure 7.1 Typical Flame

7.1. General Burner Description

The burner is a pre-mix type, which means that the fuel and air are mixed prior to entering the nozzle. Combustion occurs at the tip of the nozzle, which is about 2" in front of the tube. The flame is centered on the tube, and travels through the tube. The chamber where the nozzle is located is called the combustion chamber, and while the combustion is initiated here, very little heat is released into the combustion chamber. Figure 7.1 shows how this appears through the sight glasses on the combustion chamber. The blue flame has a very sharp cylinder-like appearance, with a diameter of less than 1". The pilot flame is typically more yellow and candle-like in appearance, but this can vary depending on the amount of secondary air being fed to the combustion chamber.

The pilot consists of several runner pilots (or ribbon burners) arranged so that there is a pilot flame in front of each nozzle. The pilot has an air inducer fitting that brings in air to the pilot gas and makes it a pre-mix pilot. A spark ignitor is placed on one end of the pilot array to start the pilot and a flame rod is placed on the opposite side, so that the pilot flame must travel throughout the full range of the burner (across the horizontal width and down the vertical length) to prove the pilot operation. At mid rates, the pilot (without main flame) will have a lazy appearance with yellow tips. At very low rates, the pilot will start to disappear, although only in color (the low CO reading is proof that it is still burning properly). At high rates, the pilot also tends to disappear due to the higher air and fuel flow rates.

7.2. Ducted Primary Air

If ducted air is required, it must be sized for 9 cubic feet of air per boiler horsepower. The connection must be made to the primary air louver on the back of the burner. Sizing the inlet air duct is the responsibility of others and should provide full flow with zero pressure drop at the air inlet.

7.3. Ignition Point

Startup of the burner normally occurs at about 1/3 to1/2 of the capacity. It is difficult to start at lower rates because of the time it takes to fill the chambers with gas before the timer times out. The ignition point can be adjusted to start at higher firing rates, including starting at full rate if this helps the operation by providing quicker load response. The non-modulating versions of the Sellers Immersion Boiler always start at full rate, and because there is no thermal shock with this boiler design, it does not require any warmup time to prevent thermal shock.

⚠CAUTION

DO NOT ATTEMPT TO START THE BURNER AT LOW RATES AS THE FUEL WILL NOT BE ABLE TO REACH THE COMBUSTION CHAMBER WITHIN THE ALLOWED TIME. THIS WILL RESULT IN FLAME FAILURES

7.4. Main Flame

The "main flame" is a series of small diameter blue flames passing from the nozzle tip into the tube. The sight glasses allow monitoring of these flames, so that the quality of combustion can be observed. A good flame will have a blue translucent appearance, with very clear surfaces. At low rates, the flame is more transparent (less actual combustion). If the flame starts to flicker on and off, that is an indication that you are at the minimum firing rate for the burner. If the flame starts to pulsate, immediately turn the burner off, as this can cause problems.

⚠ WARNING

DO NOT ATTEMP TO FIRE THE UNIT AT A LOWER FIRING RATE THAN STATED ON THE FIRE-TEST REPORT. VERY LOW RATES MAY CAUSE COMBUSTION PULSATION, CAUSING DAMAGE TO THE STACK OR OTHER EQUIPMENT. THIS IN TURN CAN CAUSE PERSONAL INJURY AND DEATH.

The primary combustion adjustment is the fuel-air-ratio. A calibrated combustion analyzer is required to set combustion. It should be capable of measuring O_2, CO and NO_x. The normal excess ranges (% O_2) for the burner vary with operation as a low NOx (30 ppm) burner or a standard burner. Table 7.1 shows these ranges.

% Rate	Standard Burner Settings, % O2	Low NOx (30 ppm) Settings, % O2
> 50%	2.5 - 4.5%	3.5 - 5.5%
30 - 50%	3.5 - 5.5%	4.0 - 6.0%
< 30%	4.0 – 6.5%	4.5 - 6.5%

Table 7.1 Typical % O_2 Levels

When adjusting the burner for operation at low NOx (30 ppm corrected to 3% O_2), the burner generally will require a higher O_2 setting to obtain the lower NOx level. A higher % O_2 (excess air) is required to cool the flame to achieve the lower NOx levels. These higher % O_2 levels are normal for lower firing rates, but not for higher firing rates. In addition, the amount of secondary air will need to be adjusted to a minimum or lower level (valve adjusted to a more closed position) to obtain the NOx settings without operating at high levels of excess air. Increasing either the primary or secondary air will result in higher % O_2 readings, but only increasing the primary air will result in lower NOx. If the secondary air setting is too high, the burner will be operating at a lower efficiency and may not make capacity.

7.5. Secondary Air

The secondary air adjustment is done primarily by trial-and-error adjustment. The purpose of the secondary air is to provide air for the pilot and to provide some air flow around the individual flames to prevent contact and disturbance with the tube, which would result in combustion noise. One setting can be used for all firing rates, but it may take some trial-and-error adjustment to determine the best setting.

To increase the amount of secondary air to the unit, turn the secondary air adjustment counterclockwise, or clockwise to decrease it. The locking nut must be properly tightened after the desired secondary air setting is achieved to prevent it from changing over time.

Insufficient secondary air will cause the pilot flame to become transparent, and combustion noise may occur. Too much secondary air will cause the % O_2 to increase above the normal operating range, and combustion noise may occur.

Monitoring the NOx level while adjusting the secondary air is one way to tell if the combustion process is within the normal range. At high rates, the NOx level should be in the 50 to 60 ppm range for a standard burner setup. As the firing rate goes down to low fire, the NOx will drop to 20 or 30 ppm for typical turndowns and maybe less than 20 ppm for turndowns in the 5:1 range. These are not absolute values, but they offer some indication of how the combustion should appear. For example, if a standard burner has a NOx reading of 35 ppm at high fire, the secondary air is probably closed too far, and should be opened more. Too little excess air may prevent the unit from reaching capacity.

For a low NOx burner that must meet a 30 ppm NOx requirement, the setting and readings would be much different at higher rates. In this case, the secondary air would be adjusted to a minimum setting while the primary air is increased to obtain a NOx level of under 30 ppm (typically adjusted to be 27 or 28 ppm).

7.6. Internal Load Controller PID Loop

The maker of the LMV5 flame safeguard, Siemens Combustion Controls, recommends a preset combination of values for the internal load controller PID loop when necessary due to outside system integrations. Sellers Manufacturing Co. does not warrant external load controllers or any other alteration to the LMV5 or safety controls.

Type	P (%)	I (Sec)	D (Sec)
Default	14.5	120	0
Very Slow	3.4	273	48
Slow	4.7	250	44
Normal	6.4	136	24
Fast	14.5	77	14
Very Fast	42.5	68	12

7.7. Impact of Changing Environment

To prevent future problems, there are several environmental variables that should be considered when tuning a boiler. The most common issue is the impact of changing combustion air temperature. The actual quantity of air supplied for combustion changes with the air temperature. For example, if the boiler is tuned using 110 °F air and set for 3% O2, then on a cold morning when it is 50 °F there will be less than 1% O2, and the burner will emit very high CO (unburned fuel) and possibly soot. The reason for this is that the fan produces a constant volume of air, but the air density changes with temperature.

A change of about 25 °F will change the air density by about 5%. The 5% excess air is approximately 1% O_2. Using this information to help set the burner will result in more efficient operation than simply running with higher excess air all the time.

For an outside installation, larger swings in air temperature should be expected, and this must be compensated for. There are controls that can compensate for changing air temperature. Another approach is to simply tune the burner on a seasonal basis.

Another variable to consider is the impact of operating at lower or higher than normal steam pressures. If the burner is tuned while operating at very low pressures, then placed into operation at a much higher pressure, the resulting combustion will be much richer than the initial setting. The reason is that the stack temperature increases with steam pressure. At 10 PSI, the steam temperature is 240 °F. At 125 PSI, the steam temperature is 353 °F. This 113 °F increase in steam temperature will increase the stack temperature by the same amount, which will increase the combustion chamber pressure, which reduces the fan output. The actual amount of change will vary by boiler but can easily result in a change of more than 1% O_2. The combustion tuning should be done at, or near the normal operating pressure.

Changes in stack draft can also cause major deviations in the combustion results. The amount of draft created changes with the temperature difference between the stack and the outside air. The draft must be controlled to within +/- 0.1” wc, and at any singe firing rate, the variation can be no more than +/- 0.05” wc. Draft controls like barometric dampers can help provide this control if needed.

Another source of combustion problems is a lack of combustion air to the boiler. Even if the boiler room is equipped with sufficient air inlets, they are sometimes blocked off because of the cold air coming into the room. If the burner does not receive enough air for combustion, it can result in high CO, unburned fuel, and delayed ignition.

⚠ WARNING

THE BURNER MUST HAVE OPEN ACCESS TO COMBUSTION AIR. BLOCKING OR RESTRICTING THE COMBUSTION AIR OPENING CAN RESULT IN EQUIPEMENT DAMAGE, INJURY OR DEATH

Elevation can change the burner pressures, so that they will be different from those stated in the factory fire test report. The factory is located at about 950 feet elevation, and higher elevations will have different readings. For every 1,000 feet over 2,000 feet of elevation, there will be a reduction of approximately 4% in capacity rating. Keep this in mind when comparing your setup data with the factory fire test.

7.8. Data Logging

Whenever a new boiler is placed in service, operating data should be recorded, compared to predicted data, and saved for future reference. Figure 7.2 shows some typical data for a unit in graphical form. This information will be extremely valuable for diagnosing problems and monitoring the condition of the equipment to help set maintenance schedules. The fire test report is the first set of data. The second set of data is collected during the startup of the unit.

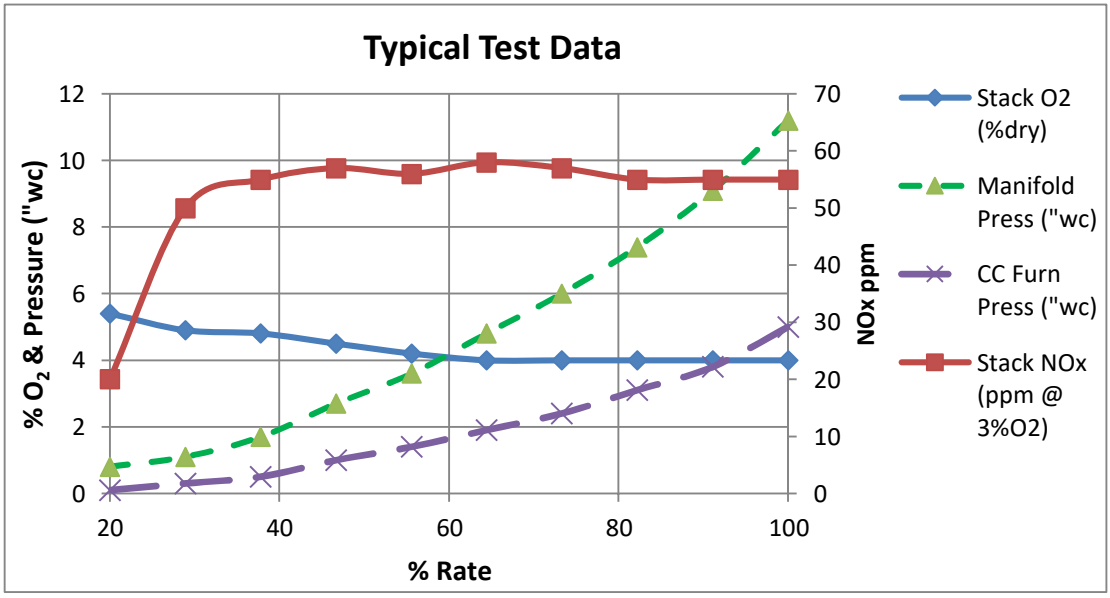


Figure 7.2 Typical Test Data

The operating data can assist the operator to spot trends and take corrective actions. Maintenance plans can be made by comparing data on a timeline to indicate when cleaning and adjustments will be required. For this data to be meaningful, the instruments and controls must be well maintained and properly calibrated.

A typical data log would include operating parameters such as pressures, temperatures, flows, draft, motor amps, firing rates, fuel and air positions, date, and time.

8. STARTUP

DANGER

BURNER STARTUP AND COMBUSTION ADJUSTMENTS SHOULD ONLY BE DONE BY A TRAINED AND EXPERIENCED SERVICE TECHNICIAN. ATTEMPTING TO PERFORM THESE TASKS WITHOUT PROPER TRAINING AND EXPERIENCE CAN RESULT IN EQUIPMENT DAMAGE, INJURY OR DEATH.

Before proceeding with the startup of the burner, be sure that the overall installation is complete and that all components are ready for operation, as detailed in Sections 6 and 7. Review this manual, as well as the manual for the controls and other supporting equipment. These manuals must be read and understood prior to starting the burner.

8.1. Initial Startup

Before attempting to start the boiler, make certain the following switches and valves are in the indicated positions.

1. The main gas shutoff cock should be in the CLOSED position.
2. The pilot shutoff cock should be in the CLOSED position.
3. The disconnect switch should be in the OFF position.
4. The manual on/off switch (see wiring diagram) should be in the OFF position. This switch is located on the front of the control cabinet.

The following equipment should be available:

- Combustion analyzer, that measures % O_2, CO ppm and NOx, with recent calibration
- Stack thermometer.
- Manometer to measure pilot gas pressure, manifold pressure and combustion chamber pressure.
- Calibrated gauges and pipe connections to measure gas supply and regulated pressure, with ranges to match the expected pressures.
- Inclined manometer to measure stack pressure (draft)
- Multimeter

WARNING

THIS MANUAL IS NOT INTENDED TO INSTRUCT UNTRAINED PEOPLE TO START THIS UNIT. THE STARTUP REQUIRES A TRAINED AND EXPERIENCED SERVICE PERSON PERFORM THE STARTUP. FAILURE TO PERFORM THE STARTUP WITH A TRAINED AND EXPERIENCED SERVICE PERSON CAN RESULT IN EQUIPMENT DAMAGE, PERSONAL INJURY OR DEATH.

The initial start-up of the burner, or any start-up after re-working the burner should use the following general procedure. Once the burner has been tuned and the controls adjusted, the burner can operate in normal or automatic operation.

1 The combustion control system should be set to “Program Stop” in the start position, and not modulate once the main flame is obtained.

2 Turn the burner switch on. This will start the combustion air fan and cause the air damper to open for the pre-purge cycle.

3 After the pre-purge cycle is complete, the damper will start to close. At a position of about 30% to 50% firing rate, verify that the pilot solenoid valve opens. The burner should shut down on pilot failure because the pilot shutoff cock is closed. If the unit properly follows this sequence, move to the next step. If the unit did not perform the proper sequence, go to the troubleshooting section, and correct the problem.

4 Open the pilot shutoff cock and then any main upstream gas valves required to provide gas to the burner. If there is a means of safely purging the gas lines, that should be done at this time.

5 Set LMV5 parameter “ProgramStop” to “44 Interval 1” (Pilot Stabilize).

6 Reset the control and re-start the unit and monitor the pilot operation. You should be able to see all the pilots light across the burner face in a few seconds. If all the pilots do not start properly, turn the burner off and follow the instructions in the troubleshooting section. Remember that for the initial startup of the burner, the failure may be due to a lack of fuel in the gas train, and that a few starting attempts may be required to fill the lines with fuel.

7 When the pilot has been established, the flame safeguard will attempt to start the main flame. Verify that the main safety shutoff valves are opening, and then closing at flame failure (the main flame will not light because the main gas shutoff cock is closed).

8 After the pilot is stabilized, set ProgramStop to “52 Interval 2” (Main Stabilize).

9 Once the main flame cycle is proven to function properly and safely, reset the control on the flame safeguard and allow the burner to re-start. Keep the leakage gas shutoff cock closed (the manual valve closest to the burner).

10 Deactivate ProgramStop.

11 To start the main flame, open the leakage gas shutoff cock, but keep your hand on it for quick shutoff if required. If the main flame does not start during the initial operation of the burner, it may be due to a lack of fuel in the gas line. It is also possible that the settings are incorrect for light-off and adjustments are needed. Refer to the troubleshooting section if the main burner fails to light after a few attempts.

12 Only adjust the air, as the proper fuel input was determined with a flow meter at the factory.

13 Once the main flame is established, it should remain at the light-off position. If the combustion analyzer shows it to be in the normal operating range, allow the unit to warm up. If the combustion is out of range, adjust it to bring it in range.

14 The next step is to bring the unit up to full rate. The manifold pressure from the factory fire test can be used as an approximate value. If the job is located at a higher elevation, adjustments to the expected gas pressure may be required. Once at the rated capacity of the unit, the gas control valve and servo should be fully opened (about 70 degrees) and the regulator should be adjusted to provide the correct rate. This will allow the gas control valve to have good control at low rates.

15 If needed, adjust the fuel-air ratio at high fire. Check the NOx reading. For a low NOx boiler, the NOx should be under the limit by about 10%. For other units, the NOx should be around 50 ppm. The secondary air should be adjusted to help obtain the desired NOx, which will allow the unit to operate in the most efficient manner. Verify that you have not set the secondary air in a position that is close to causing combustion noise, and if needed, adjust to provide some safety margin. See Section 7 for details on combustion settings.

16 If needed, adjust the fuel-air curve from high to low fire, keeping in mind that the points should be closer together at lower rates because small changes in the fuel and damper position cause relatively large flow changes, and the fuel-air ratio can be too rich or lean between points. Always start with factory curve settings first since the unit functioned properly with those settings during the factory fire-test.

17 Modulate the unit several times from low to high fire, and cycle on and off to verify that the settings are well established. It is not uncommon for some hysteresis to exist in the equipment, and the settings should be made to allow for an average of these values.

At this point, the burner should be operating, but the startup is not complete until the safety switches have been checked and adjusted. These checks need to be done periodically, as outlined in Section 9 of this manual.

⚠ DANGER

FAILURE TO PROPERLY ADJUST AND VERIFY THE OPERATION OF THE SAFETY CONTROLS CAN CAUSE EQUIPEMENT DAMAGE, INJURY OR DEATH.

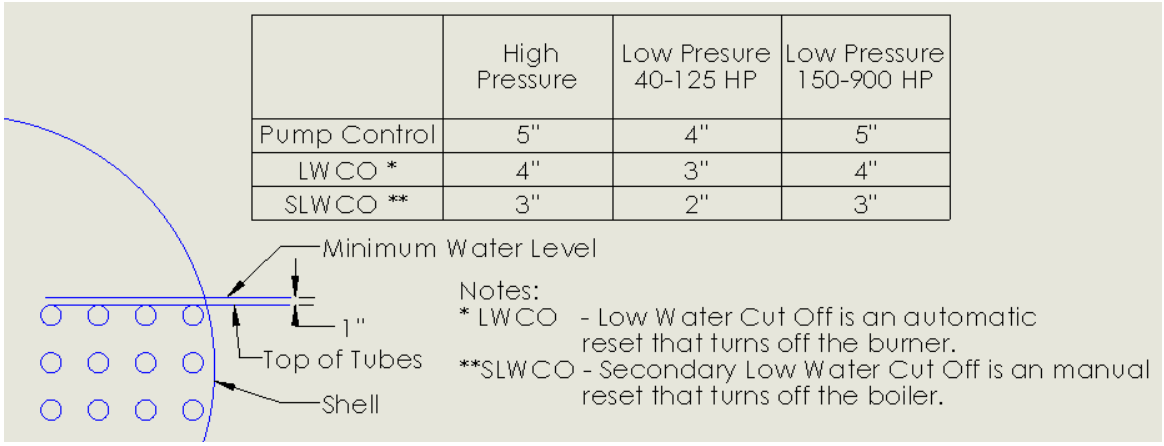
8.2. Safety Controls Set-Up

There are several safety controls on the boiler that must be properly set and routinely checked to provide adequate safety for the operation of the boiler. The information given here covers the normal adjustments of typical safety controls but is not intended to cover all controls that may be installed on the boiler. In addition, vendors can change the design and operation of the safety controls over time, and the installer must verify that they have the correct tuning procedure for each control. Finally, the flame safeguard and combustion controls will contain many safety features that must also be addressed in this process. These are not covered in this manual because of the wide variety of controls that can be used. Refer to the specific manual for your control to cover these items.

8.2.1. Water Level Controls

Inspect the low water cutoff and pump control as well as the auxiliary low water cutoff (if equipped). Check for freedom of movement of the float, which can be observed when the pump is running, and that the water level in the sight gauge is moving. It is critical that these controls function properly to provide safe operation. Frequent blowdown of the control is also required to prevent sludge buildup under the float, which can also prevent proper operation of the controls.

The best method to check these controls is to drain some water from the boiler and watch the level control response. The controls should operate at the positions shown in Figure 8.1. There is a minimum water level plate permanently attached to the side of the boiler that is located 1 inch above the top of the tubes and can be used to check the positions of the water level control functions.



	High Pressure	Low Presure 40-125 HP	Low Pressure 150-900 HP
Pump Control	5"	4"	5"
LWCO *	4"	3"	4"
SLWCO **	3"	2"	3"

Figure 8.1 Water Level Control Points

DANGER

WATER LEVEL CONTOLS MUST BE CHECKED FOR PROPER OPERATION. IF THE WATER LEVEL CONTROLS ARE NOT WORKING CORRECTLY, MAJOR EQUIPMENT DAMAGE WILL OCCUR, AND INJURY OR DEATH MAY OCCUR.

8.2.2. Gas Pressure Switches

Adjust the low gas pressure switch to be approximately 10% below the lowest expected gas pressure. Use a gauge or manometer at the same point as the low gas pressure switch to determine the lowest gas pressure. At this lowest pressure, adjust the switch until the switch breaks and turns the burner off. From this point, adjust the pressure setting to a point 10% lower than the trip point. Cycle the burner to ensure that it functions properly. If this setting causes nuisance shutdowns, reduce the pressure setting.

Adjust the high gas pressure switch to be 10% above the highest expected gas pressure. Use a gauge or manometer at the same point as the high gas pressure switch to determine the highest gas pressure. At this highest pressure, adjust the switch until the switch breaks and turns the burner off. From this point, adjust the pressure setting to a point 10% higher than the trip point. Cycle the burner to ensure that it functions properly. If this setting causes nuisance shutdowns, increase the pressure setting.

If the gas pressure has pulsations that do not allow the pressure setting to be reasonably close to the operating points, consider adding an orifice block to the control if the control manufacturer offers one. This will steady the pressures that the switch sees and will not trip because of momentary pulses.

8.2.3. Combustion Air Proving Switch

The combustion air proving switch measures the pressure from the combustion air fan and is used to prove that the fan is providing air for combustion. It must be adjusted at startup to match the field conditions. At low fire, turn the adjusting screw in (clockwise) until the burner trips out. Then turn the adjusting screw out (CCW) 1 ½ turns from the point of shutdown. Start the burner and verify that it functions properly at all rates.

8.2.4. High Limit Control

The boiler is equipped with a high limit pressure control that will shut the boiler down if the set pressure is exceeded. This switch must never be bypassed electrically or mechanically (by installing a stop valve in the line). This is a manual-reset switch and will require that someone manually press the reset button to reset the switch and allow the boiler to operate. The setting on this switch should be no higher than 85% of the relief valve setting, but also above the operating pressure setting to prevent nuisance shutdowns. If the adjustment range of the switch goes beyond the relief valve setting, a scale lock should be installed to prevent adjustment to a pressure higher than the relief valve setting.

8.3. Normal Operation

Normal operation is a term describing the daily automatic operation of the boiler in the system. Prior to normal operation, the boiler must have been properly installed and started by a qualified contractor or combustion specialist. The owner and operating personnel should have received training in the operation and maintenance of the boiler.

If the boiler has been out of service for a short interval, like overnight or a weekend, the following sequence should be included in the startup sequence. There will be other actions required to support the auxiliary equipment and controls, so these are not all the actions required. The boiler should be visually inspected for any abnormal conditions. Any problems found should be corrected prior to operation of the boiler.

1. Confirm that the boiler water level is correct.
2. Make sure the on/off switch is off and turn the main power on.
3. Open the main gas shutoff valve, the pilot gas shutoff valve, and other gas valves that may have been closed.
4. Reset low gas pressure switch and any other control requiring a reset after power interruption.
5. Turn on the boiler by placing the on/off switch in the on position.

9. MAINTENANCE

9.1. General

The dependable and consistent operation of your Sellers boiler will be maintained if a careful maintenance schedule is followed. This section of the manual describes periodic inspection and maintenance requirements.

a. Keep the boiler, the burner, and the entire boiler room clean. Do not allow fuel, water, or steam to leak anywhere. A clean boiler room is essential to reliable boiler operation.

b. Never close vents supplying air to the boiler room when firing the boiler. If cold air currents cause difficulty with other equipment, air ducts should be installed to direct the flow of fresh air.

c. Repair all leaks promptly. All piping connections to the boiler and all accessories should be maintained leak-free because even a minor leak, if neglected, may soon become serious. This applies especially to water level control piping and manhole and handhole gaskets. If serious leaks occur shut down the boiler immediately and reduce pressure. Close return and supply valves to isolate boiler if the system allows. Do not attempt to make repairs while the boiler is under pressure or at a high temperature.

9.2. Safety Checklist for Inspection

The following general procedures should be followed when the boiler needs to be opened for inspection. These procedures cover the most common areas that an annual inspection would cover.

a. Before entering a boiler, lock out and tag all equipment items with movable parts connected to boiler and fuel system and place a sign at the operating controls indicating that a workman is in the boiler.

b. Before entering a boiler, make sure it is properly isolated from all fuel, flue gas, steam, and water sources. Make sure that it is properly vented and obtain an air sample to check for breathing quality. Use low voltage or explosion proof lights.

c. Notify the person in charge at the site when beginning and upon completion of the inspection.

d. Inspect with another person, so if assistance is required, help will be close at hand.

e. Always be aware of the nearest escape routes.

f. Before closing manholes and doors, it is essential that all personnel are out of the boiler.

9.3. Water Side Checklist

a. The tubes and tube sheets should be free of deposits and scale buildup. If these exist, the water treatment program is not working correctly and needs to be modified. The scale and deposits must be cleaned off the tubes and tube sheets. In some cases, a chemical cleaning is required to accomplish this. Contact a water treatment specialist for these areas.

b. All internal fittings should be in serviceable condition and securely installed in the correct position.

c. Look for evidence of corrosion. Oxygen pitting on tubes is an indication that the oxygen and other gases are not being removed in the feedwater, and the treatment program must be modified.

d. Look for erosion of mating surfaces of manholes, handholes and flanges.

e. Note the location of trouble spots in the logbook and compare them to previous log entries to see if they are the same and have not been corrected by upgrades to the treatment program.

f. The water side (tubes and tube sheets) should be free from extraneous material such as dirt, tools, rags and so on.

9.4. Fire Side Checklist

a. Stack dampers should be examined for free movement and signs of potential corrosion failure.

b. Breeches should be cleaned of dirt and soot.

c. The breeching and stack seams should be tight, and there should not be any holes.

d. Record any findings in the logbook and compare to earlier log entries to determine if corrective actions are needed.

9.5. Maintenance Schedule

Daily	Weekly	Monthly	Seasonal	Annual	As Needed	Component / Item	Recommended Action or Test	Boiler Operator	Qualified Technician
X						Burner flame	Visual inspection of burner flame	X	
X						Air and fuel valve	Smooth and free travel	X	
X						Draft controls	Smooth and free travel	X	
X						Gas fuel pressure	Record in logbook, compare trends	X	
X						Pilot flame	Visual inspection of pilot flame	X	
X						Pilot flame signal	Record in logbook, compare trends	X	
X						Main flame signal	Record in logbook, compare trends	X	
X						Temperatures & pressures	Record in logbook, compare trends	X	
X						Blowdown, water quality	Frequent blowdown per water quality	X	
X						Water quality test	Test water quality (per required plan)	X	
X						Operating control setting	Verify proper on/off and modulating pressures	X	
X						Check vessel for leaks	Look for leaks in handhole, manhole, safety valves and other components	X	
X						Fuel leaks	Check for gas leaks by smell	X	
X						Logbook data	Enter operating data in logbook	X	
	X					Flame failure response	Close pilot manual valve during pilot, verify shutdown	X	
	X					Flame failure response	Close main manual valve during pilot, verify shutdown	X	
	X					Fuel valves	Verify POC action by cycling off if continuous operation	X	
		X				Front door seal	Check front door seal for leakage, adjust or replace	X	
		X				Stack, breeching, draft control	Visual inspection, free operation	X	
		X				Combustion air	Visual inspection for clean and open pathways	X	
		X				Safety interlocks	Check operation of safety interlocks (POC, gas pressure, combustion air, high limit and LWCO & ALWCO)		X
			X			Combustion tuning	Verify combustion settings, $\%O_2$, CO and NOx		X
			X			Safety valves	Manually run safety valves (lift top). They should have free flow and close tightly	X	
			X			LWCO & ALWCO	Open control, inspect for sludge and free operation		X
				X		Safety shutoff valves	Inspect valves for wear and leakage, replace if needed		X
				X		Gas line	Check drip leg for material buildup, clean as needed	X	
				X		Burner hardware	Inspect burner hardware, clamps and wiring. Adjust and replace as needed		X
				X		Fuel valve leak tests	Perform leak tests on main and pilot valves		X
				X		Inspect vessel fireside	Open front and rear doors and inspect tubes for cleanliness. Clean if needed		X
				X		Inspect vessel waterside	Open handholes and manholes, inspect waterside. Clean if needed		X
				X		LWCO, ALWCO & controls	Open and rod all piping, check wiring for heat damage		X
				X		Gas strainer	Remove and clean gas strainer		X
				X		Sight ports	Clean sight port glass, replace if needed	X	
				X		Ignitor	Inspect for wear and replace or adjust		X
				X		Flame rods	Inspect pilot and main flame rods, replace if needed		X
				X		Condensate drain	Check condensate drain line for free flow	X	
				X		Combustion air fan	Clean combustion air fan	X	
					X	Flame safeguard replacement	Replace flame safeguard as needed		X

10. TROUBLESHOOTING

Problem	Possible Cause
Burner does not start	1. No power to controller A. Main disconnect switch open B. Blown control circuit fuse C. Loose or broken electrical wire D. BMS/EMS system command or signal
	2. Limit circuit not completed, no power at end of limit string A. Pressure is above setting B. Water level is below needed level C. Check manual reset switch on ALWCO (if equipped) D. Fuel pressure out of range (low or high pressure)
	3. Fuel valve interlock circuit not completed A. Fuel interlock switch on gas valve not made B. Lose connection or broken wire
No Ignition in pilot cycle	1. Lack of spark A. Electrode grounded or porcelain cracked B. Improper electrode setting, see Section 6 C. Lose terminal on ignition cable or shorted cable D. Inoperative ignition transformer E. Insufficient or no voltage at pilot ignition circuit terminal.
	2. Spark but no flame A. lack of fuel - no gas pressure, closed valve, broken line first startup … B. Inoperative pilot solenoid C. Insufficient or no voltage at pilot ignition circuit terminal D. Initial startup, gas lines empty E. Too much air (reduce secondary air flow) F. Manual valve closed, blocking gas flow
	3. Running interlock circuit not completed A. Combustion air switch not made or faulty or not set correctly B. Motor starter interlock not closed
	4. Insufficient gas flow to fill manifold before time out A. Increase ignition rate to increase gas flow B. Increase time allowed before shutdown (within the control, if available)
Pilot flame starts but locks out on trial for pilot flame	1. Pilot flame rod not properly positioned A. Re-position flam rod, see Section 6
	2. Flame rod does not work A. Check wiring to and from flame rod B. Replace flame rod
	3. Flame too small to operate flame rod A. Adjust pilot flame. The control can be locked in the pilot cycle with a program lock feature to provide more time for adjustments

Problem	Possible Cause
Pilot flame but no main flame	1. Insufficient pilot flame A. Pilot gas pressure too low B. Firing rate of burner too high
	2. insufficient gas flow to burner A. Manual gas valve closed B. Main gas valve inoperative C. Flow control valve not properly set (too little flow) D. Gas pressure regulator not properly set E. Initial startup, gas lines empty
	3. Flame rod inoperative
Combustion Noise, pulsations	1. Improper fuel-air ratio A. Excess air too high or low B. Hysteresis causes some high or low excess air during modulation C. Set points too far apart, causing rich/lean zones between points
	2. Secondary air adjustment incorrect. A. Adjust for smooth operation at all rates. See Section 7.
	3. Improper stack layout A. Draft too high (limit is +/- 0.1"wc) B. Sharp elbows or entries causing flow disruptions C. Draft controls upsetting draft on modulation
Shutdown occurs during firing.	1. Loss or restriction of fuel flow or pressure
	2. Defective fuel valve, loose connection
	3. Weak flame signal, marginal flame detection
	4. Safety controls set too close to tripping point
	5. Improper fuel-air ratio (too lean)
	6. BMS/EMS system command or signal
	7. Gas supply quality
	8. Improper stack design or rooftop stack issue
Fuel-air-ratio. changes	1. Air leak around air damper, fan inlet cone or front door A. Re-seal gaskets
	2. Fuel or air valve sticky, or servo not positioning correctly A. Check fuel and air valve for proper positioning and replace as needed