

CLEAVER-BROOKS

Model 5 Boiler

Size 8000 Low Water Volume



Manual Part No. 750-215

11/04



SAFETY PRECAUTIONS AND ABBREVIATIONS

Safety Precautions

It is essential to read and understand the following safety precautions before attempting to operate the equipment. Failure to follow these precautions may result in damage to equipment, serious personal injury, or death. A complete understanding of this manual is required before attempting to start-up, operate or maintain the equipment. The equipment should be operated only by personnel who have a working knowledge and understanding of the equipment.

The following symbols are used throughout this manual:



This symbol indicates a potentially hazardous situation which, if not avoided, could result in serious personal injury, or death.



This symbol indicates a potentially hazardous situation which, if not avoided, could result in damage to the equipment.

Note: This symbol indicates information that is vital to the operation of this equipment.

Abbreviations

Following is an explanation of the abbreviations, acronyms, and symbols used in this manual.

AC	Alternating Current
AR	Automatic Reset
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
BHP	Boiler Horsepower
BTU	British Thermal Unit
°C	Degrees Celsius
CFH	Cubic Feet per Hour
Cu Ft	Cubic Feet
DC	Direct Current
°F	Degrees Fahrenheit
FM	Factory Mutual
FS	Flame Safeguard
ft	Feet
GPM	Gallons per Minute
Hd	Head
HT	Height
HTB	High Turndown Burner
HZ	Hertz
In H ₂ O	Inches of Water
IRI	Industrial Risk Insurance
Lb	Pound
LWCO	Low-Water Cut-Off
M	Million
MFD	Micro-Farad
MR	Manual Reset
NEC	National Electric Code
No.	Number
pH	Measure of the degree of acid or base of a solution
P/N	Part Number
PPM	Parts Per Million
PR	Program Relay
psi	Pounds Per Square Inch
SAE	Society of Automotive Engineers
scfh	Standard Cubic Feet per Hour
T	Temperature
TC	Temperature Control
TI	Temperature Gauge

CLEAVER-BROOKS

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DO NOT OPERATE, SERVICE, OR REPAIR THIS EQUIPMENT UNLESS YOU FULLY UNDERSTAND ALL APPLICABLE SECTIONS OF THIS MANUAL.

DO NOT ALLOW OTHERS TO OPERATE, SERVICE, OR REPAIR THIS EQUIPMENT UNLESS THEY FULLY UNDERSTAND ALL APPLICABLE SECTIONS OF THIS MANUAL.

FAILURE TO FOLLOW ALL APPLICABLE WARNINGS AND INSTRUCTIONS MAY RESULT IN SEVERE PERSONAL INJURY OR DEATH.

TO: Owners, Operators and/or Maintenance Personnel

This operating manual presents information that will help to properly operate and care for the equipment. Study its contents carefully. The unit will provide good service and continued operation if proper operating and maintenance instructions are followed. No attempt should be made to operate the unit until the principles of operation and all of the components are thoroughly understood. Failure to follow all applicable instructions and warnings may result in severe personal injury or death.

It is the responsibility of the owner to train and advise not only his or her personnel, but the contractors' personnel who are servicing, repairing or operating the equipment, in all safety aspects.

Cleaver-Brooks equipment is designed and engineered to give long life and excellent service on the job. The electrical and mechanical devices supplied as part of the unit were chosen because of their known ability to perform; however, proper operating techniques and maintenance procedures must be followed at all times. Although these components afford a high degree of protection and safety, operation of equipment is not to be considered free from all dangers and hazards inherent in handling and firing of fuel.

Any "automatic" features included in the design do not relieve the attendant of any responsibility. Such features merely free him of certain repetitive chores and give him more time to devote to the proper upkeep of equipment.

It is solely the operator's responsibility to properly operate and maintain the equipment. No amount of written instructions can replace intelligent thinking and reasoning and this manual is not intended to relieve the operating personnel of the responsibility for proper operation. On the other hand, a thorough understanding of this manual is required before attempting to operate, maintain, service, or repair this equipment.

Because of state, local, or other applicable codes, there are a variety of electric controls and safety devices which vary considerably from one boiler to another. This manual contains information designed to show how a basic burner operates.

Operating controls will normally function for long periods of time and we have found that some operators become lax in their daily or monthly testing, assuming that normal operation will continue indefinitely. Malfunctions of controls lead to uneconomical operation and damage to the equipment. In most cases, these malfunctions can be traced directly to carelessness and deficiencies in testing and maintenance.

It is recommended that a boiler room log or record be maintained. Recording of daily, weekly, monthly and yearly maintenance activities and recording of any unusual operation will serve as a valuable guide to any necessary investigation.

Most instances of major boiler damage are the result of operation with low water. We cannot emphasize too strongly the need for the operator to periodically check the low water controls and to follow good maintenance and testing practices. Cross-connecting piping to low water devices must be internally inspected periodically to guard against any stoppages which could obstruct the free flow of water to the low water devices. Float bowls of these controls must be inspected frequently to check for the presence of foreign substances that would impede float ball movement.

The waterside condition of the pressure vessel is extremely important. Waterside surfaces should be inspected frequently to check for the presence of any mud, sludge, scale or corrosion.

The services of a qualified water treating company or a water consultant to recommend the proper boiler water treating practices are essential.

The operation of this equipment by the owner and the operating personnel must comply with all requirements or regulations of their insurance company and/or other authority having jurisdiction. In the event of any conflict or inconsistency between such requirements and the warnings or instructions contained herein, please contact Cleaver-Brooks before proceeding.

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A. THE BOILER



Figure 1-1 Model 5 Steam Boiler

The Cleaver-Brooks Model 5 Boiler is a packaged steel boiler consisting of a pressure vessel, oil or gas burner, burner controls, forced draft fan, air control damper, and associated components.

The Model 5 Boiler is of watertube construction with welded membrane waterwalls arranged so that the products of combustion travel the length of the furnace, reverse themselves and then pass between the furnace waterwalls and the convection waterwalls. Complete combustion takes place in the furnace.

The M5 8000 LWV uses the Profire burner.

The M5 8000 LWV is primarily offered in the Province of Ontario to comply with the Ontario Operating Engineer's Act requirement for Low Water Volume (< 75 Imperial Gallons operating water content). The M5 Size 8000 LWV standard unit is cUL approved for sale throughout Canada.

In addition to the operating water content the following features are standard construction for M5 8000 LWV and are necessary for compliance with the low volume requirement of the Ontario Operating Engineer's Act:

- 1) Guarded plant control system
- 2) McD-M 193-7 water column (or LevelMaster) with modulating Feedwater valve
- 3) Insulated steam drum (insulated from combustibles).
- 4) Low fire hold

Model 5 Size 8000 LWV is designated M5 P-(100, 200, 700)-8000- 150-WV.

The type of fuel used by the boiler determines the classification. These are:

- Series 100 Light oil (No. 2) only
- Series 200 Light oil (No. 2) and gas
- Series 700 Gas only

A boiler equipped to burn oil and gas includes equipment for each distinct fuel. Since the burner uses only one type of fuel at a time, a gas/oil selector switch is incorporated in the combination units.

The 150 designates 150 psig MAWP. The gun style burner is designated GL-(100,200,700)-4. The M5 8000 LWV is only offered as a 150 psig MAWP (Maximum Allowable Working, Pressure) steam boiler, "S" stamped to ASME Section I. The maximum input is 8,00,000 Btu/hr. Minimum input is approximately 3,200,000 Btu/hr.

Installation should also conform to provincial and local codes governing such equipment. Prior to installation the proper authorities having jurisdiction are to be consulted, permits obtained, etc. Installation should also conform to state and local codes governing such equipment. Prior to installation, the proper authorities having jurisdiction are to be consulted, permits obtained etc. All Model 5 boilers in the above series comply, when equipped with optional equipment, to Factory Insurance Association (F. I. A.), Factory Mutual (FM) or other insuring underwriters requirements.

B. THE BURNER

The M5 Size 8000 LWV differs from M5 Sizes 1500-6000 in that it utilizes an inverted housing Profire burner compared with the integral windbox style burner. Burner is factory mounted as shown in **Figure 1-2**.



Figure 1-2 Model 5 Profire Burner

Notice

The boiler or burner may be constructed with features not covered in this manual, refer to the submittal information supplied for the boiler.

Also refer to the individual component literature shipped with the boiler (i.e. Flame Safety Program Relay).

The Profire burner model is designated as follows:

PFH080 LOP-4L, oil only, (100 Series)

PGH080 LGP-4L, Combination Gas-Oil, (200 Series)

PFH080 NGX-4L, Gas Only, (700 series)

ProFire™					
Packaged Burner Systems					
		Natural Gas (CFH) Gaz (PCH)	Press. (In. WC) (Po. col. d'eau)	Liquid (GPH) Fluide (GPH)	Press. (PSI) (LPC)
Input Range	Max.	8000	21.4	57.1	160
Gam me De Puissance	Min.	3200	1.9	24.2	70

Figure 1-4 Profire Data Plate

ProFire™ Packaged Burner System					
	Gas (CFH) Gaz (PCH)	Press. (In. WC) (Po. col. d'eau)	Liquid (GPH) Fluide (GPH)	Press. (PSI) (LPC)	
Input Range Gam me De Puissance	Max.				
	Min.				
Fuel Type Type de combustible					
Heating Value Valeur calorifique					
Overfire Draft (Max.) Tirage maximum dans le foyer (In. W.C.) (Po. col. d'eau)					
Current Characteristics Caractéristiques Electriques					
Load Charge	HP	VOLTS	PH.	HZ.	AMPS. FUSE
Main Circuit principal					
Control Circuit Circuit de controle					
Fan Motor Moteur du ventilateur					
Air Compressor Compresseur d'air					
Circulating Pump Pompe Circulant					
Oil Heater Chaleur Huile					
Control Circuit Circuit de controle					
Transformer					
	PRIMARY				
	SECONDARY				
Cleaver Brooks DIVISION OF AMCA/CHAM, INC. MILWAUKEE, WISCONSIN					

Figure 1-3 Burner Data Plate



Figure 1-5 Profire Name Plate

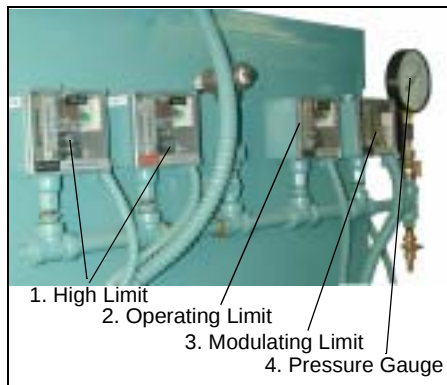


Figure 1-6 Steam Controls

C. STEAM CONTROLS

1. High Limit Pressure Control (**Figure 1-6**): Breaks a circuit to stop burner operation on a rise of pressure above a selected setting. It is adjusted to stop the burner at a preselected pressure above the operating limit control setting. The high limit pressure control is equipped with a manual reset.
2. Operating Limit Pressure Control (**Figure 1-6**): Breaks a circuit to stop burner operation on a rise of boiler pressure at a selected setting. It is adjusted to stop or start the burner at a preselected pressure setting.
3. Modulating Pressure Control (**Figure 1-6**): Senses changing boiler pressures and transmits the information to the modulating motor to change the burner firing rate when the manual-automatic switch is set on "automatic."
4. Pressure Gauge (**Figure 1-6**): Monitors the internal pressure of the boiler

D. LEVEL CONTROL, WATER COLUMN & SAFETY VALVE

The optional Level Master (**Figure 1-7**) low water cutoff and pump control uses solid state and microprocessor based technology. The system uses magnetostrictive technology, eliminating levers and switches. Traveling up and down the probe is a 2", non contact and non wearing titanium float(**Figure 1-8**). The panel display(**Figure 1-7-A**) allows for monitoring and resetting control parameters. See manual 750-193 for information of setup and operation.

This float-operated control breaks the circuit to stop burner operation in the event boiler water drops below the master low water cutoff point. The standard low water cutoff is the McD M-193-713, float and lever operated low water cutoff.

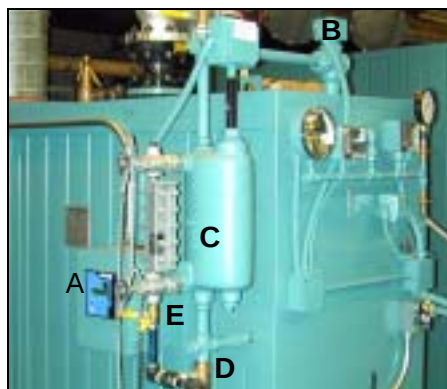


Figure 1-7 Level Master Low Water Cutoff and Level Control



Figure 1-8 Level Master Cutaway

• Water Column - (**Figure 1-7-C**)

This assembly houses the low water cutoff and modulating feedwater control and includes the water gauge glass, gauge glass shutoff cocks, and trycocks. The gauge glass provides a means for visually determining water level.

• Water Column Drain Valve - (**Figure 1-7-D**)

The water column drain valve is provided so that the water column and its piping can be flushed regularly to assist in maintaining cross-connecting piping and float bowl clean and free of sediment. A similar drain valve is furnished with auxiliary low water cutoff (optional equipment) for same purpose.

• Water Gauge Glass Drain Valve - (**Figure 1-7-E**)

This valve is provided to flush the gauge glass.

- Auxiliary Low/High Water Cutoff - (**Figure 1-7-B**) (Optional equipment)

The manual reset type requires resetting in order to start the burner after a low water condition.

Safety Valve(s) (Figure 1-9): Prevent buildup over the design pressure of the pressure vessel. The size, rating and number of valves on a boiler is determined by the ASME Boiler Code. The safety valves and the discharge piping are to be installed to conform to the ASME code requirements. The installation of a valve is of primary importance to its service life. A valve must be mounted in a vertical position so that discharge piping and code-required drains can be properly piped to prevent buildup of back pressure and accumulation of foreign material around the valve seat area. Apply only a moderate amount of pipe compound to male threads and avoid overtightening, which can distort the seats.

Use only flat-jawed wrenches on the flats provided. When installing a flange-connected valve, use a new gasket and draw the mounting bolts down evenly. Do not install or remove side outlet valves by using a pipe or wrench in the outlet.

E. BURNER CONTROLS

The burner can be equipped with special operating controls, various types of flame safety control systems.

The wiring and dimension diagrams and construction reference list (available with the burner) confirm the specific features and equipment included. Refer to Figures 1-8 and 1-9 for component locations. The following list describes components and basic functions of the burner.

1. **Electrical Control Cabinet (Figure 1-10):** The control cabinet houses many of the electrical control components and the flame safeguard. The operator control switches and indicator lights are located on the face of the control cabinet door. The following controls and indicators are provided:
 - **Flame Failure Light:** Illuminates (red) 20 seconds after the flame is extinguished. When this happens, the system automatically shuts down; manual reset of the flame safeguard is required.


Warning

Only properly certified personnel such as the safety valve manufacturer's certified representative can adjust or repair the boiler safety valves. Failure to follow these instructions could result in serious personal injury or death



Figure 1-9 Safety Valve

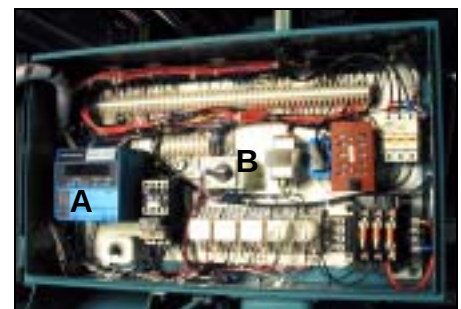


Figure 1-10 Control Panel Open



Figure 1-11 Control Panel Closed

- Load Demand Light: Illuminates (white) when the boiler operating controls indicate a demand for hot water or steam.
 - Burner Switch: Activates or deactivates the operating cycle of the flame safeguard control.
 - Manual Flame Control: When in Manual Mode, it provides manual adjustment of the burner firing rate between low-fire and high-fire operation.
 - Manual-Auto Switch: Allows the operator to override the automatic boiler controls for manual firing rate adjustment.
 - Fuel Valve Light: Illuminates (green) when the selected fuel valve is energized.
 - Low Water Light: Illuminates (red) when the boiler low-water cutoff control is activated.
2. Flame Safety Control(**Figure 1-10-A**): The flame safety controls the operating sequences of the combustion system (prepurge, pilot, firing, and shutdown). The control also monitors the flame, using a scanner which is sensitive to specific flame frequencies. The flame safety also automatically shuts down the burner when the flame signal becomes too weak. Different types of flame safety devices can be installed in the combustion systems. Check the wiring diagram for your burner for information on the specific unit installed on your burner.
 3. Fuel Selection Switch (**Figure 1-10-B**): Allows the operator to select either gas or oil as the active fuel on combination burners. (The switch is located inside the control cabinet.)



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Profire Burner

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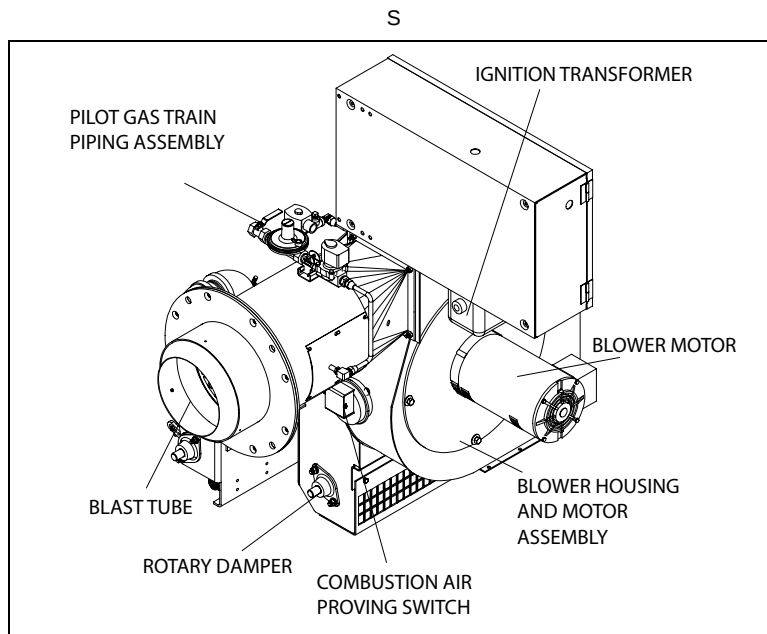


Figure 2-1 Profire Component Location (Left Side)

A. FIRING TUBE

Blast Tube (Figure 2-1). The blast tube functions as a duct for combustion air, and houses the fuel nozzle(s), gas pilot assembly, diffuser, and air baffle assemblies.

B. BLOWER HOUSING/MOTOR/DAMPER

Blower Housing (Figure 2-1). The blower housing encloses the impeller. The fan drive motor is mounted directly to the blower housing.

Blower Motor (Figure 2-1). The electric motor drives the combustion air fan and the oil pump (if so equipped).

Impeller (Not Illustrated). The impeller is designed with backwards-inclined blades. It is located inside the blower housing, and is driven by the combustion air fan motor. The impeller provides combustion air to the burner assembly. Removing the impeller requires the use of the impeller puller, part number 943-388 (**Figure 2-2**)

Rotary Damper (Figure 2-1): The airbox is attached to the inlet side of the blower housing. It serves as the inlet and flow regulating valve for combustion air, and houses the rotary air damper. The rotary damper modulates the combustion air between low fire and high fire conditions. The shaft and linkage assembly connects the modulating motor to the rotary damper shaft and to the fuel valve linkage assemblies.



Figure 2-2 Impeller Puller

C. GAS COMPONENTS

Note: Depending upon the requirements of the insurance carrier or other governing agencies, the gas flow control system, or gas train, may consist of some, or all, of the following items. Refer to your boiler to determine those that are applicable.

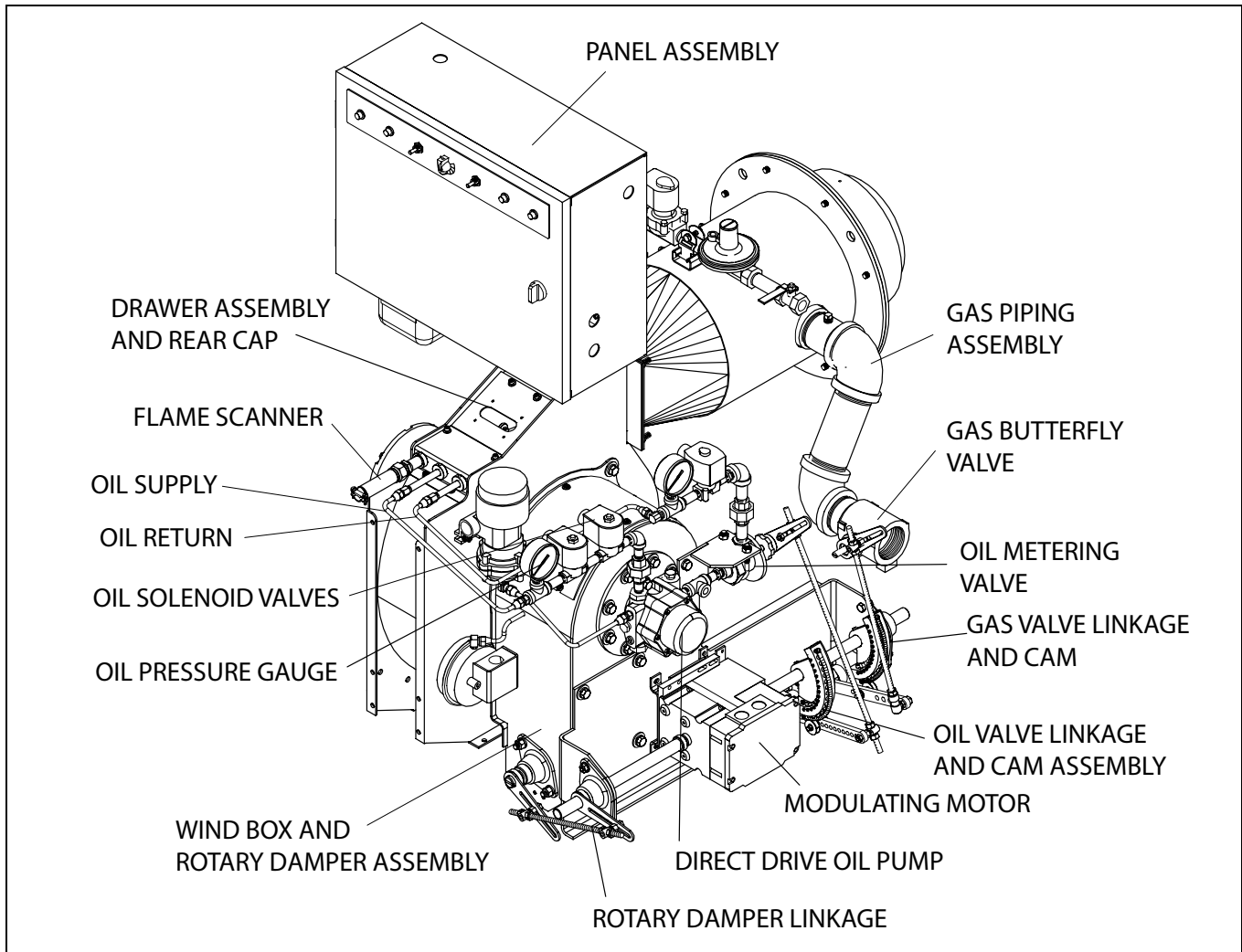


Figure 2-3 Profire Component Locations (Right Side)

Gas Butterfly Valve (Figure 2-3). The gas butterfly valve regulates the flow rate of natural gas into the burner. The gas butterfly valve is connected, by linkage and a jack shaft, to the modulating motor, which provides the rotary motion to open and close the valve.

Gas Valve Linkage and Cam (Figure 2-3). The valve linkage transfers the modulating motion from the main air shutter shaft to the fuel metering valve shafts. The linkage provides a means of adjustment to maintain the correct fuel-to-air

ratio over the entire burner operating range, high fire to low fire.

Main Gas Valve (Figure 2-4):Electrically actuated shut-off valve that opens to admit gas to the burner. Depending upon boiler size and/or the applicable regulatory requirements, this may be a diaphragm valve or, more generally, a motorized type valve. The motorized valve may be equipped with a proof of closure device connected to the pre-ignition interlock circuitry of the flame safety control. This prevents initiation of the ignition cycle unless the valve is closed. The requirements may further call for a second motorized valve downstream of the first. These operate simultaneously.

Gas Vent Valve (Optional) A normally open solenoid valve installed between the two main gas valves to vent gas to the atmosphere should any be present in the main gas line when the gas valves are de-energized. The vent valve closes when the gas valves are energized.

Main Gas Cock For manually opening or closing the main fuel gas supply. A second shut-off cock, downstream of the main gas valve(s), may be installed to provide a means of shutting off the gas line whenever a test is made for leakage across the main gas valve.

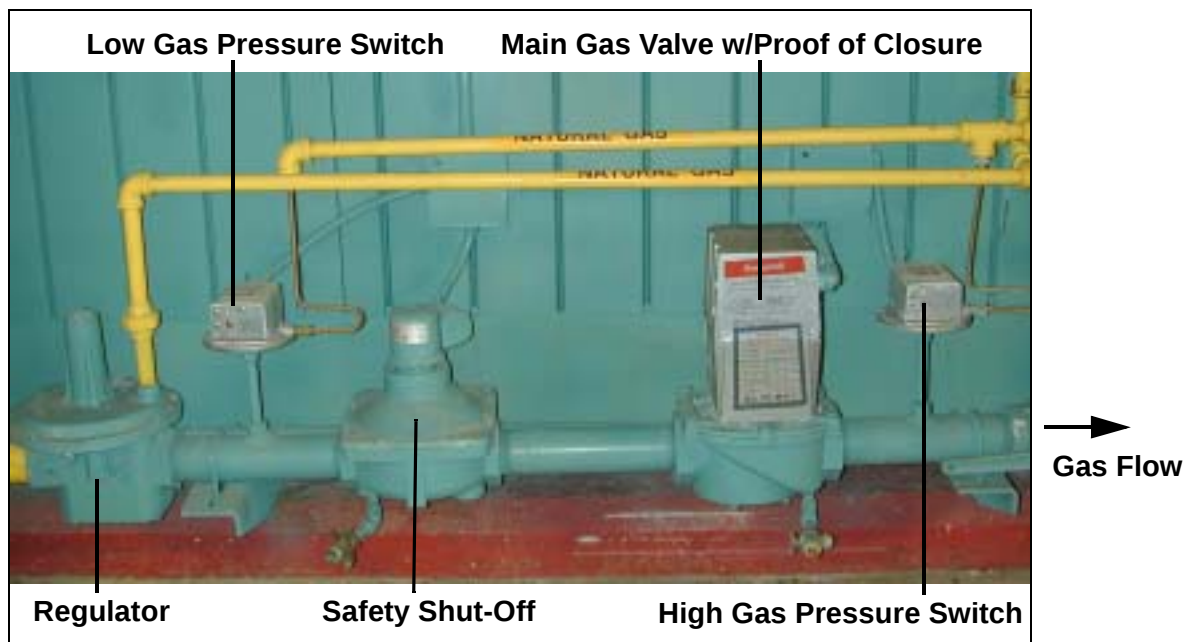


Figure 2-4 Gas Train Components

Low Gas Pressure Switch (Figure 2-4): A pressure actuated switch that is closed whenever main gas line pressure is above a preselected pressure. Should the pressure drop below this setting, the switch contacts will open a circuit causing the main gas valve(s) to close, or prevent the burner

from starting. This switch is usually equipped with a device that must be manually reset after being tripped.

High Gas Pressure Switch (Figure 2-4): A pressure actuated switch that is closed whenever main gas line pressure is below a preselected pressure. Should the pressure rise above the setting, the switch contacts will open a circuit causing the main gas valve(s) to close, or prevent the burner from starting. The switch is usually equipped with a device that must be manually reset after being tripped.

Leakage Connection. The body of the gas valve has a plugged opening that is used whenever it is necessary or desirable to conduct a test for possible leakage across the closed valve.

D. OIL COMPONENTS

Oil Pump (Figure 2-3). The oil pump provided for oil burning is coupled to an extension of the combustion air fan shaft.

Oil Metering Valve (Figure 2-3). The oil metering valve regulates the flow rate of oil into the burner. The oil metering valve is connected by linkage and a jack shaft to the modulating motor, which provides the rotary motion to open and close the valve.

Oil Solenoid Valves (Figure 2-3). The oil solenoid valves are in series and downstream of the oil metering valve in the supply line to the oil burner assembly. Two valves are provided. These valves are simultaneously energized to open and release fuel oil to the burner. The valves close to stop combustion when oil is the fuel.

Low Oil Pressure Switch.

E. IGNITION COMPONENTS

Ignition Transformer (Figure 2-1). The ignition transformer produces the high voltage required for spark generation by the pilot electrode(s).

Pilot Gas Train (Figure 2-1). The standard pilot gas train consists of a manual stopcock, a gas pressure regulator, and a solenoid-operated gas shut-off valve. The gas pilot valve assembly controls a relatively small flow rate of natural gas to operate the gas-electric pilot.

Gas Pilot Shut-Off Cock For manually opening or closing the gas supply to gas pilot valve.

Gas Pressure Gauge Indicates gas pressure to pilot. (Optional)

Gas Pressure Regulating Valve Reduces incoming gas pressure to a value that assures a satisfactory pilot.

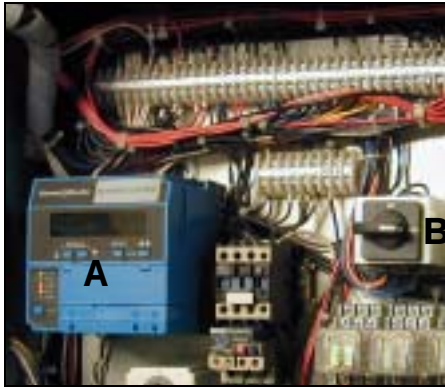


Figure 2-5 Panel Open, Flame Safety and Fuel Selector Switch

F. SAFETY AND CONTROLS

Flame Safety (Figure 2-5, A): The flame safeguard controls the operating sequences of the combustion system (prepurge, pilot, firing, and shutdown). The control also monitors the flame, using a scanner which is sensitive to specific flame frequencies. The flame safeguard also automatically shuts down the burner when the flame signal becomes too weak. Different types of flame safeguard devices can be installed in the combustion systems. Check the wiring diagram for your burner for information on the specific unit installed on your burner.

Fuel Selector Switch (Figure 2-5, B): Allows the operator to select either gas or oil as the active fuel on combination burners.

Combustion Air Proving Switch (Figure 2-1). The combustion air proving switch provides confirmation to the flame safeguard that the combustion air fan is providing air flow. The fuel supply valves will not open if this switch does not sense adequate air pressure.

Modulating Motor (Figure 2-3). The modulating motor is coupled to the jack shaft that operates the main air shutter and the fuel valve linkages. The modulating motor produces the torque and rotary positioning required for firing rate control.

Rear Cap (Figure 2-3). The rear cap contains the locking setscrew for adjustment of the diffuser relative to the air baffle, and also the flame scanner for the flame safeguard. The rear cap must be removed to enable removal of the oil gun assembly.

The actual controls furnished with any given boiler will depend upon the type of fuel for which it is equipped.

Boilers having optionally ordered features may have control components not listed here.

G. AUTOMATIC IGNITION

The burner is ignited by an interrupted type gas pilot

The gas pilot flame is ignited automatically by an electric spark. Fuel for the pilot is supplied from the utility mains or from a tank (bottle) supply. Flow rate (flame size) is regulated by a pressure regulator.

At the beginning of the ignition cycle, the pilot gas solenoid valve and ignition transformer are simultaneously energized. The ignition transformer high voltage current for the igniting spark which arcs between the single electrode within the pilot tube and the wall of the tube itself. The gas pilot solenoid and transformer are de-energized after main flame is ignited.

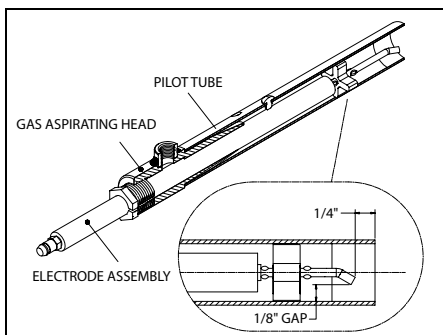


Figure 2-6 Gas Pilot Assembly

H. COMBUSTION AIR

Air for the combustion of fuel is delivered by the forced draft fan of the burner.

The supply of combustion air is regulated by modulating the air damper to maintain the correct ratio of air to fuel for efficient combustion throughout the range of firing rates.

I. OPERATION - NATURAL GAS

The gas flow system is shown with the direction of flow indicated by the arrow. (**Figure 2-4**)

Metered gas from the utility flows into the burner's gas piping through a main gas shut-off cock; through a pressure regulator where the pressure is reduced to the pressure suitable to the burner's requirements; through an electrically operated main gas valve and through a butterfly gas valve to the burner. Gas required for pilot operation is taken from this line prior to the main gas shut-off cock.

Gas for the pilot operation flows through a shut-off cock into a pressure regulator where the pilot operating pressure is established. A solenoid valve controls the flow of the gas and when energized (opened) allows the gas to flow to the pilot where it is mixed with combustion air. This mixture is ignited by a controlled electric spark to establish the pilot flame. The pilot burns only during the time required for main flame ignition.

At the beginning of the ignition cycle, the pilot solenoid valve is energized through circuitry in the programmer control and the pilot ignited. When pilot flame is proven, the programming control energizes the electrically operated main gas valve, allowing flow through the butterfly valve to the burner. The rate of flow to the burner depends upon the position of the vane in the butterfly valve. This is mechanically controlled by the modulating motor and varied in the same manner as the air damper, thus properly proportioning gas and combustion air.

The gas pressure regulator's diaphragm and valve positions itself to the degree required to maintain a constant pressure on its downstream side. The pressure to which its spring is set reduces the incoming pressure to prevent over-firing while still providing the volume of gas required by the burner and at a pressure high enough to overcome the pressure loss due to the frictional resistance imposed by the burner system and the control valves.

Gas flows through the burner orifice ring to enter the combustion zone where it is intimately mixed with combustion air to produce main flame.

The boiler has a modulating motor for controlling firing rate. This type of motor is reversible and will move in either direction or stop at any position within its range. Through a linkage arrangement it controls the air damper and fuel

valve(s) to maintain the air-fuel ratio throughout the firing range.

The main fuel valve(s) cannot be energized (opened) unless the combustion air proving switch is closed to indicate a sufficient supply of combustion air.

Some insurance requirements specify two main fuel valves. Additional requirements call for a normally open vent valve to be placed between them for venting gas should any be present in main gas line when main gas valves are de-energized. The vent valve closes when the main gas valves open.



Section 3

The Pressure Vessel

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A. GENERAL

This chapter is devoted primarily to the waterside care of the pressure vessel.

The operator must familiarize himself with this chapter before attempting to place the unit into operation.

Waterside care is of prime importance. The subject of water supply and treatment cannot adequately be covered in this manual. The services of a feedwater consultant should be obtained and their recommendations followed.

Water treatment is a must and has an important bearing on the type of service your boiler provides. This is true for both steam and hot water boilers. It is essential to boiler life and length of service. Constant attention to this area will pay dividends in the form of longer life, less down time, and prevention of costly repairs. Care taken in placing the pressure vessel into initial service is vital. The waterside of new boilers and new or remodeled steam or hot water systems may contain oil, grease or other foreign matter. A method of boiling out the vessel to remove these accumulations is described later in this chapter.

Feedwater equipment should be checked and ready for use. See that all valves, piping, boiler feed pump, and receiver are installed in accordance with prevailing codes and practices.

If the boiler is to be used for temporary heat, as for example in new construction, properly treated water must be used. Failure to do so can be detrimental to the boiler.

Boilers, as part of a hot water system, require proper circulation and the system must be operated as intended by its designer to avoid severe, possibly damaging, stresses occurring to the pressure vessel. Refer to **Section** of this chapter.

B. CONSTRUCTION

All Cleaver-Brooks boilers are built to ASME Code requirements and may be identified by the Code symbol stamped on the pressure vessel. **S** indicates power boilers: **H** indicates heating boilers.

Heating boilers are defined as low pressure steam boilers for operation at pressures not exceeding 15 psi and/or hot water boilers operating at pressures not exceeding 160 psi and/or temperatures not exceeding 250°F: and manufactured to the ASME heating boiler Code.

Power boilers are steam boilers designed for pressures in excess of 15 psi or high temperature water boilers operating in excess of 250°F; and manufactured to the ASME power boiler Code.

C. WATER REQUIREMENTS

1. Hot Water Boiler

Air Removal

All Cleaver-Brooks hot water boiler outlet connections include a dip tube which extends into the top drum. This dip tube reduces the possibility of any air (which may be trapped at the top of the drum) entering into the system.

Any oxygen or air that may be released in the boiler will collect or be trapped at the top of the drum and will find its way out of the boiler through the air vent tapping. This tapping, on the top center line of the drum should be piped into the expansion or compression tank.

Continuous Flow

It is required that the system be piped and the controls arranged so that there will be water circulation through the boiler under all operating conditions. The minimum circulation is 1/2 to 1 gallon per minute per boiler horsepower. Constant circulation through the boiler eliminates the possibility of stratification and results in more even water temperature to the system. Constant circulation is mandatory for a boiler equipped with an internal coil. A blend pump is included as standard construction on M5 Hot Water boilers.

Multiple Boiler Installation

When multiple boilers of equal or unequal size are used, care must be taken to insure adequate flow through each. If balancing cocks or orifice plates are used, a significant pressure drop (for example, 3 to 5 psi) must be taken across the balancing device to determine required flow rates.

If care is not taken to insure adequate flow through the boilers this can result in wide variation of firing rate between them.

Pressure Drop

There will be a pressure drop of less than 9 feet head (1 psi – 2.31 ft. hd.) through all standardly equipped Cleaver-Brooks boilers operating in any system which has more than the 20°F. temperature drop. This drop will vary with boiler size. Consult factory for specific information.

Pressure

The design of the system and the usage requirements will often dictate the pressure exerted upon the boiler. Some systems are pressurized with air or with an inert gas, such as nitrogen. Caution must be exercised to make sure that the proper relationship of pressure to temperature exists within the boiler so that all of its internal surfaces are fully wetted at all times.

When initially firing a newly installed boiler or when cutting an existing boiler into an operating system, the boiler or boilers to be cut into operation **MUST** be pressurized equal to the system and/or other boilers prior to cutting in.

2. Steam Boiler

Feed Pump Operation

Make certain that all valves in the water feed line are open **BEFORE** turning on the pump motor to prevent possible damage to feed pump mechanism. After opening valves, momentarily energize feed pump motor to establish correct pump rotation. With correct rotation, close boiler feed pump entrance switch. Pump should shut down when water level reaches proper level.

Feedwater pumps must have adequate capacity to maintain water level under all operating conditions. Check feedwater pumps periodically and maintain as necessary to prevent unexpected breakdowns.

Minimum Boiler Water Temperature

If the temperature of the flue gas is reduced to the dew point, the condensed water can cause corrosion in the fireside of the boiler and the breeching. This condensation problem is more severe on the unit which operates intermittently or because it is oversized for the actual load. This is not a matter which can be controlled by boiler design, since an efficient boiler extracts all the possible heat from the combustion gases. This problem can be minimized by maintaining an adequate boiler water temperature. For greatest protection, a minimum return water temperature of 180°F. is recommended, with outlet temperature at 180°F minimum.

D. WATER TREATMENT

Maximum effectiveness and long trouble-free life of pressure vessels at the lowest cost consistent with good engineering and operating practice are functions of properly treated boiler feedwater. The recommendations of a water consultant or a reliable water treating company must be followed rigidly to prevent the presence of unwanted solids and corrosive gases.

Caution

Prior to operating a pump, carefully check alignment of flexible coupling if one is used on the pump. A properly aligned coupling will last a long time and provide trouble-free mechanical operation.

Caution

Fire a cold unit slowly to avoid undue stressing of the pressure vessel parts. To assist in this, all hot water boilers are equipped with a minimum 10 minute low fire hold before the boiler can increase its firing rate. Failure to heed this caution could result in serious equipment failure and possible personal injury or death.

Objectives of water treatment in general are:

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

The accomplishment of these objectives generally require proper feedwater treatment before and after introduction of the water into the boiler. The selection of pre-treatment processes depends upon the water source, its chemical characteristics, amount of make-up water needed, plant operating practices, etc. These treating methods include filtering, softening, de-mineralizing, derating and pre-heating. After treatment involves chemical treatment of the boiler water.

Because of the variables involved, no one “boiler compound” can be considered a “cure-all” nor is it advisable to experiment with homemade treating methods. Sound recommendations and their employment should be augmented by a periodic analysis of the feedwater, boiler water, and condensate.

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

It is recommended that a properly sized water meter be installed in the raw water make-up line to accurately determine the amount of raw water admitted to the boiler (steam or hot water) to aid the water treatment program in maintaining proper waterside conditions.

The general feeling exists that a hot water boiler does not require water treatment, but this is a false assumption. The recommendations of a reliable water treating company or a water consultant should be followed rigidly. Even though these generally operate on a closed system and blowdown is seldom practiced, the need remains to be alert to system water losses. A water meter is recommended for water make-up lines.

E. CLEANING

- Hot Water and Steam Piping

Steam and water piping systems connected to the boiler may contain oil, grease or foreign matter. These impurities

must be removed to prevent damage to pressure vessel heating surfaces. On steam systems the condensate should be wasted until tests show the elimination of undesirable impurities. During the period that condensate is wasted, attention must be given to the treatment of the raw water used as make up so that an accumulation of unwanted materials or corrosion does not occur. Follow the advice of your water treating company.

On hot water systems, chemical cleaning is generally necessary and the entire system should be drained after treatment. Consult water treatment companies for recommendations, cleaning compounds and application procedures.

- Pressure Vessel

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

The pressure vessel and the steam and return lines or hot water piping represent, in effect, a closed system. Although the steam and return (condensate) lines or the hot water piping system may have been previously cleaned it is possible that:

1. Cleaning has been inadequate.
2. Partial or total old system is involved.
3. Conditions may prevent adequate cleaning of piping.

The installation and operating conditions to which the boiler will be subjected must be considered and the cleaning of the waterside of the pressure vessel must be provided during the course of initial start-up.

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

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

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

Any oil or grease present on the heating surfaces must be removed promptly by a boil-out with an alkaline detergent solution.

F. BOIL-OUT OF A NEW UNIT

The internal surfaces of a newly installed boiler may have oil, grease or other coatings for various reasons beyond the manufacturer's control. These coatings must be removed since they lower the heat transfer rate and could cause overheating of heating surfaces. Before boiling out procedures may begin, the burner must be ready for firing. The operator must be familiar with the procedure outlined under burner operation.

Your water consultant or water treating company will be able to recommend a cleaning or boil-out procedure. In the event such service is unavailable or is yet unselected, the following information may be of assistance.

Suggested procedure for boiling out new units prior to initial firing is as follows:

1. Tri-sodium phosphate and caustic soda are the suggested chemicals for cleaning of boilers. One pound of each chemical should be used for every 50 gallons of water. See Table 2-1 for boiler water capacity.

Boiler Model	Water — Gallons	Water — Weight
	Normal (Steam) Flooded	Normal Flooded
1500	89	739
2000	89	739
2500	122	1013
3000	122	1013
3500	153	1270
4000	153	1270
4500	187	1552
5000	187	1552
6000	218	1809
8000	255	2124

2. When dissolving chemicals, the following procedure is suggested. Warm water should be put into a suitable container. Slowly introduce the dry chemical into the water stirring at all times until the chemical is completely dissolved. Add the chemical slowly and in small amounts to prevent excessive heat and turbulence.
3. An over flow pipe should be attached to one of top drum openings and routed to a safe point of discharge. A water relief or safety valve tapping is usually used. See following paragraph.
4. Water relief valves and steam safety valves must be removed before adding the boil-out solution so that neither it nor the grease which it may carry will

Caution

Temperature of initial fill of water for hydrostatic tests, boil-out, or for normal operation should be as stated in the ASME Boiler Code.

Caution

Use of a suitable face mask, goggles, rubber gloves, and protective garments is strongly recommended when handling or mixing caustic chemicals. Do not permit the dry material or the concentrated solution to come in contact with skin or clothing

contaminate these valves. Use care in removing and re-installing valves.

5. All valves in the piping leading to or from the system must be closed to prevent cleaning solution from getting into the system.
6. Fill pressure vessel with clean water until top of tube openings in upper drum are covered. Add the cleaning solution and then fill to the top.
7. The boiler should then be fired intermittently at a low rate sufficient to hold solution just at the boiling point. Boil the water for at least 5 hours. Do not produce steam pressure.
8. Allow a small amount of fresh water to enter boiler to create a slight overflow that will carry off surface impurities.
9. Continue boiling and overflow until water clears.
10. Stop the burner and drain boiler using caution that the hot water is discharged with safety.
11. Remove cover plate in upper drum and inspection plugs in lower drum and wash the waterside surfaces thoroughly using a high pressure water stream.
12. Inspect surfaces and if not clean repeat the boil-out.
13. After closing openings and re-installing safety or relief valve(s), fill the boiler and fire until water is heated to at least 180°F. to drive off any dissolved gases which might otherwise corrode the metal.

The above procedure may be omitted in the case of units previously used or known to be internally clean, however, consideration must be given to the possibility of contaminating materials entering the boiler from the system.

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

On a hot water system chemical cleaning of the entire system is generally necessary and the entire system should be drained after treatment. Consult a water treatment company for recommendations, cleaning compounds and application procedure.

G. WASHING OUT

1. Steam Boiler

No later than 3 months after initially placing the boiler into operation and thereafter as conditions warrant, the pressure vessel should be drained after being properly cooled to near ambient temperature, handhole cover or closure plate in the upper drum and handhole covers in the lower drum removed and internal waterside surfaces inspected for corrosion, pitting, or formation of deposits.

2. Hot Water Boiler

In theory, a hot water system and boiler that has been initially cleaned, filled with treated water, and with no make-up water added will require no further cleaning or treatment. However, since the system (new or old) may allow entrance of air and unnoticed or undetected leakage of water, introductions of raw water make-up or air may lead to pitting, corrosion and formation of sludge, sediment, scale, etc., on the pressure vessel waterside.

If there is any doubt then the pressure vessel waterside should be inspected no later than 3 months after initially placing the boiler into operation and periodically thereafter as indicated by conditions observed during inspections.

Flushing of Pressure Vessel Interior

Upon completion of inspection, the pressure vessel interior should be flushed out as required with a high pressure hose. If deposits are not fully removed by such flushing, this may require immediate consultation with your water consultant or feedwater treatment company, and in extreme cases, it may be necessary to resort to acid cleaning. Professional advice is recommended if acid cleaning is required.

These inspections will indicate the effectiveness of the feedwater treatment. The effectiveness of treatment, the water conditions, and the amount of fresh water make-up required are all factors to be considered in establishing frequency of future pressure vessel wash-out periods. Subsequent inspections will indicate the effectiveness of the water treating program as well as the suitability of the intervals between washouts. The feedwater consultant or water treatment company service should include periodic pressure vessel inspection and water analysis.

H. BLOWDOWN — STEAM BOILER

Boiler water blowdown is the removal of some of the concentrated water from the pressure vessel and its replacement with feedwater so that a lowering of the concentration in the boiler water occurs.

Solids are present in the feedwater even though this water is treated prior to use with external processes that are

designed to remove unwanted substances which contribute to scale and deposit formations. However, none of these processes are in themselves capable of removing all substances and regardless of their high efficiency, a small amount of encrusting solids will be present in the boiler water.

Solids become less soluble in the high temperature of the boiler water and tend to crystallize and concentrate on heating surfaces. Internal chemical treatment is, therefore, required to prevent the solids from forming harmful scale and sludge.

Scale has a low heat transfer value and acts as an insulation barrier. This retards heat transfer, which not only results in lower operating efficiency and consequently higher fuel consumption, but, more importantly can cause overheating of boiler metal.

This can result in tube failures or other pressure vessel metal damage causing boiler down time and costly repairs.

Scale is caused primarily by calcium and magnesium salts and silica. Any calcium and magnesium salts in the boiler water are generally precipitated by the use of sodium phosphate along with organic materials to maintain these precipitates or “sludge” in a fluid form. The solids such as sodium salts and suspended dirt do not readily form scale, but as the boiler water boils off as relatively pure steam, the remaining water is thicker with the solids. If this concentration is permitted to accumulate, foaming and priming will occur and the sludge can cause harmful deposits that bring about overheating of the metal.

The lowering or removal of this concentration requires the use of boiler water blowdown.

1. Types of Blowdown

There are two principal types of blowdown: intermittent manual blowdown and continuous blowdown.

Intermittent Blowdown

Manual or sludge blowdown is necessary for the operation of the boiler regardless of whether or not continuous blowdown is employed.

The blowdown tapping is located in the bottom drum. In addition to lowering the dissolved solids in the pressure vessel water, blowdown also removes a portion of the sludge which accumulates in the lower drum.

Equipment generally consists of a quick opening valve and a shut-off valve. These, along with the necessary piping, are not normally furnished with the boiler, but supplied by others. All piping must be to a safe point of discharge. Piping must be properly supported and free to expand.

 Caution

Boiler and water level control blowdown must be performed on a regular basis to ensure that concentrated solids are removed from the boiler and in order to avoid damage to the equipment

Continuous Blowdown

Continuous blowdown is used in conjunction with a surface blow-off tapping and is the continuous removal of concentrated water.

The surface blow-off opening, located in the rear head of the upper drum, is slightly below the working water level for the purpose of skimming surface sediment, oil or other impurities from the surface of the pressure vessel water.

A controlled orifice valve is used to allow a continual — yet controlled — flow of concentrated water.

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

The flow control valve and piping are generally provided by others. All piping must be to a safe point of discharge.

2. Frequency of Intermittent Blowdown

When continuous blowdown is utilized, intermittent blowdown is primarily used to remove suspended solids or sludge. The continuous blowdown removes sediment and oil from the surface of the water along with a prescribed amount of dissolved solids.

When surface or continuous blowdown is not utilized, manual blowdown is used to control the dissolved or suspended solids in addition to the sludge.

In practice, the valve(s) of the bottom blowdown are opened periodically in accordance with an operating schedule and/or chemical control tests. From the standpoint of control, economy and results, frequent short blows are preferred to infrequent lengthy blows. This is particularly true when suspended solids content of the water is high. With the use of frequent short blows a more uniform concentration of the pressure vessel water is maintained.

In cases where the feedwater is exceptionally pure, or where there is a high percentage of return condensate, blowdown may be employed less frequently since less sludge accumulates in the pressure vessel. When dissolved and/or suspended solids approach or exceed pre-determined limits, manual blowdown to lower these concentrations is required.

It is generally recommended that steam boilers be blown down at least once in every eight hour period, but this may vary depending upon water and operating conditions. The blowdown amounts and a schedule should be recommended by a water treating company or a water consultant.

A hot water boiler does not normally include a tapping for surface blowdown but does have a drain opening in the lower drum. Blowdown is not commonly practiced with a hot water system, however may be necessary depending upon the condition of system, variable water and make-up. The need

remains to be alert to system water losses and corresponding amount of raw water make-up. A water meter with a small flow rate is recommended for water make-up lines.

3. Manual Blowdown Procedure

Blowdown is most effective at a time when generation of steam is at the lowest rate since feedwater input then is also low, providing a minimum dilution of the boiler water with low concentration feedwater.

Make sure blow-off piping, and tank, if used, are in proper operating condition and discharge vents clear of obstruction, and that waste is piped to a point of safe discharge. The valve installation must be in accordance with applicable codes.

Most blow-off lines are provided with two valves, generally a quick opening valve nearest the boiler and a slow opening globe type valve downstream. Two slow opening valves or tandem valves may be used. Valves will vary depending upon pressure involved and make or manufacture.

If a quick opening valve and a globe type or slow opening valve are in combination, the former is normally opened first and closed last with blowing down accomplished with the globe or slow opening valve. If seatless valves are installed follow the manufacturer's recommendations.

When opening the second or down stream valve, crack it slightly to allow the lines to warm up, then continue opening slowly.

The length of each blow should be determined by actual water analysis. Lowering the water in the gauge glass approximately 1/2" is often acceptable as a guide to adequate blow, however, this should not be interpreted as a rule since water analysis procedures should prevail. If the glass cannot be viewed by the party operating the valve, another operator should watch the glass and direct the valve operator.

Close the downstream (slow opening) valve first and as fast as possible. Then close the valve next to the boiler. Slightly crack the downstream valve and then close it tightly.

A blow-off valve must not be left open and the operator must never leave until the blowdown operation is completed and the valves closed.

I. PERIODIC INSPECTION

Insurance regulations or local laws will require a periodic inspection of the pressure vessel by an authorized inspector. Sufficient notice is generally given to permit removal from service and preparation for inspection.

When shutting down, the load should be reduced gradually and the pressure vessel cooled at a rate that avoids

Warning

Be sure thwt the blowdown piping is in good condition, the discharge vents are clear of obstruction, and that the waste is piped to a safe point of discharge, in order to avoid serious personal injury or death.

damaging temperature differential that can cause harmful stresses. Vessels should not normally be drained until all pressure is relieved again to prevent uneven contraction and temperature differentials. Draining the unit too quickly may cause the baking of deposits that may be present on the heating surfaces. Some heat, however, may be desirable to dry out the interior of the boiler.

If the internal inspection is being made at the request of an authorized inspector, it is well to learn from him whether he desires to observe the conditions prior to cleaning or flushing of waterside surfaces.

Handhole openings are located in the drum heads. These openings provide access and permit waterside inspection of the drum.

The handhole plates should be tightened securely to prevent leakage. Always use a new gasket when resealing. Make sure that seating surfaces are clean. Snugging the nut after a warm-up period will help provide a tight seal.

Be certain that proper gaskets are available along with any other items needed to place the unit back into operation after inspection.

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

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

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

The fireside surfaces should also be thoroughly cleaned so that metal surfaces, welds, joints, etc. plus any previous repairs can be readily checked. See **Section** .

Be sure that steam valves, system valves, (hot water) feedwater valves, blow-off valves, all fuel valves, valves to expansion tanks, and electrical switches are shut off prior to opening inspection cover or removing plugs. Flashlights rather than extension cords are recommended as a safety factor. Cleaners should preferably work in pairs.

Clean out the low water cut-off piping, the water level controls and cross connecting piping. Replace water gauge glass and clean out water cocks and tricocks.

Also check and clean drain and blowdown valves and piping.

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



Figure 3-1. Rear Inspection Plate

J. FIRESIDE CLEANING

Soot and non-combustibles are effective insulators and if allowed to accumulate will reduce heat transfer to the water and increase fuel consumption. Soot and other deposits can be very moisture absorbent and may attract moisture to form corrosive acids which will deteriorate fireside metal.

Clean out should be performed at regular and frequent intervals, depending upon load, type and quality of fuel, internal boiler temperature, and combustion efficiency. A stack temperature thermometer can be used as a guide to clean out intervals, since an accumulation of soot deposits will raise the flue gas temperature.

All oil fired units are equipped with water washing devices for the convection surfaces. See separate section pertaining to water washing.

In extreme cases, soot or other combustion deposits may be present in the furnace area. These will have to be removed by brushing or scraping. Entry to this area is gained through the access door. Brush-out or vacuum any loosened deposits.

Inspect the refractory and repair or maintain as outlined in the refractory section.

The vent connection stack should be cleaned at regular intervals. Commercial firms are available to perform this work. The stack should be inspected for damage and repaired as required.

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

K. WATER WASHING — FIRESIDE (OIL FIRED UNIT)

An oil fired boiler has water washing lances located in the passageway between the convection tube wall and the furnace tube wall on both sides of the boiler (see **Figures 3-1**). Their purpose is to provide a means of washing away any soot that may have built up on the tube wall surfaces. The frequency of water washing depends upon operating conditions. Boilers with long operating runs at high fire and with efficient flame will require less frequent cleaning than those with frequent cycling, prolonged low fire operation, improperly adjusted combustion, etc.

A periodic log of stack temperatures determined through use of a stack thermometer will alert the operator to the need for cleaning. A marked increase in temperature over an established level indicates a loss in efficiency and heat transfer caused by soot deposits.

A flexible hose from the building water supply should be attached to the hand operated valve on the lance. Do not use boiler feedwater. In the event permanent piping or tubing is provided instead of a hose, a suitable swivel joint must be installed to allow rotation of the lance. A shutoff valve at the supply point is recommended.

Remove the drain caps or fully open valves in the drain piping — depending upon installation. If drain piping is not provided, the use of a drain hose is suggested. If the boiler is situated adjacent to a drain it may be possible to merely let the discharge wash water run into it. Thoroughly wet the floor first to aid in floating away soot.

Bring the boiler up to its approximate operating pressure or temperature before washing. With the burner in low fire, open one lance valve and rotate the lance in an arc that assures washing panel surfaces. Note the reference mark on the lance to indicate location of spray holes. Continue rotating back and forth until drain water runs clear. Opening and closing the valve to obtain frequent, short sprays provides better results than a steady flow.

Care must be taken to be sure that water is draining away at approximately the same rate as its input to avoid flooding or entering the furnace.

When drain water is clear, repeat the process in the other bank. After washing, the close the lance valve and when draining stops, shut the drain valves or replace caps.

To be sure that all moisture is evaporated, continue firing for at least 45 minutes after washing so that the convection area is thoroughly dried. During this drying period the burner may be cycled to the high fire position.

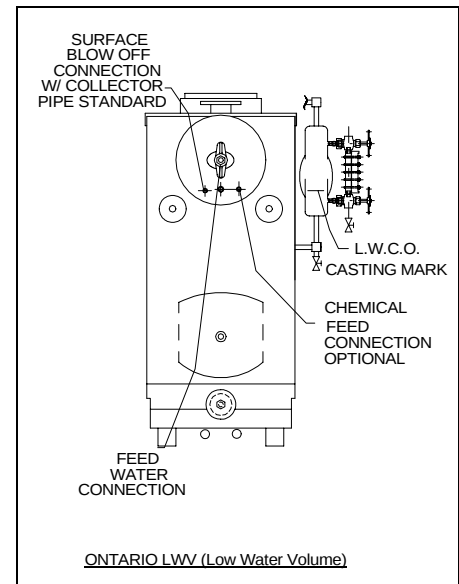


Figure 3-2. Rear Upper Head 150 psi Steam Model 8000

The front end of the water drain troughs on the under side of the drum are equipped with capped openings. These openings enable the trough to be flushed with a hose, if necessary, to remove any accumulation. When doing this, make sure that the drains are open and that water is draining away.

L. PREPARATION FOR EXTENDED LAY-UP

A boiler used for heating or seasonal loads or for stand-by service may have an extended period of non-use. Special attention must be given so that neither waterside nor fireside surfaces are allowed to deteriorate from corrosion.

There are two methods of storage — wet or dry. Your water consultant or feedwater treating company can recommend the better method, depending upon circumstances in a particular installation. Section VII of the ASME Code also contains information relating to laying up a boiler.

1. Dry Storage

Dry storage is generally employed when the boiler will be out of service for some time or when freezing temperatures may occur. In this method, the boiler must be thoroughly dried, since any moisture will cause corrosion. Both waterside and fireside surfaces must be clean of all scale and deposits, soot, etc. Steps must be taken to eliminate moisture by placing moisture absorbing material, such as quicklime or silica-gel, on trays inside the drums and furnace. These trays should not be completely filled with the material, so that the corrosion liquid gathered in them does not overflow onto the boiler surfaces. Refractories should be brushed clean and wash-coated. fireside surfaces may be sprayed or coated with an anti-corrosive material. All openings to pressure vessel must be shut tightly. Feedwater and steam valves should be closed. Damper and vents should be closed to prevent air from reaching fireside surfaces. Periodic inspection must be made and the absorption materials renewed.

Care must be taken to remove all of the moisture absorbing material before any attempt is made to refill the boiler. Serious damage can result otherwise. As a precaution it is recommended that warning signs be conspicuously posted. These signs could be similar to the following



Important

Moisture absorption material has been placed in the waterside and furnace areas of this boiler. This material must be removed before any water is placed in boiler and before burner is fired. Inspect periodically and replace with fresh and/or regenerated materials

2. Wet Storage

Wet storage is generally used for a boiler held in standby condition or in a case where dry storage is not practical. The possibility of freezing temperatures must be considered. Care must be taken to protect metal surfaces. Variables preclude definite recommendations, however, it is suggested that after the vessel is drained and cleaned that it be refilled to overflowing with treated water. If deaerated water is not available, the boiler should be fired to boil the water for a

short period of time. Additional chemicals may be suggested by the water consultant to minimize corrosion. Internal water pressure should be maintained at greater than atmospheric pressure. Nitrogen is often used for this purpose. fireside surfaces must be thoroughly cleaned and refractories should be wash-coated. It is advisable, if feasible, to occasionally circulate the water to prevent stratification and to insure that fresh inhibitor is in contact with all the surfaces. If additional chemicals are added for this idle period, more frequent blowdowns may be required when the boiler is returned to service to rapidly reduce the chemical composition to normal operating levels.

During storage, steps should be taken to protect the exterior components from the possibility of rust or corrosion. These parts should be coated with a rust inhibitor and protected from moisture and condensation. Operating controls, regulators, valves, etc. should be drained and dried. Electrical equipment should likewise be protected. Keeping the control circuit energized may prevent condensation from forming in the control cabinet or on the flame safeguard control.

Notes



Section 4

Sequence Of Operation

A. General	4-2
B. Circuit and Interlock Controls	4-2
C. Sequence of Operation - Oil or Gas	4-5
D. Flame Loss Sequence	4-7

A. GENERAL

Chapter 4 outlines the electrical sequencing of various controls through the pre-purge, ignition, run, and shutdown cycles of the burner.

The program relay establishes the sequence of operation and directs the operation of all other controls and components to provide an overall operating sequence.

Abbreviations for the various electrical components are listed in Figure 4-1. The sequences outlined in Chapter 4 employ specific nomenclature to aid in applying the text to the wiring diagram.

The burner and control system are in starting condition when the following conditions exist:

- Boiler water is up to the correct level, closing the low-water cutoff switch.
- The low-water light (panel) is off.
- The operating limit pressure control (steam boiler) or the operating limit temperature control (hot water boiler) and high limit pressure or temperature control are below their cutoff setting.
- All applicable limits are correct for burner operation.
- The load demand light glows.
- All entrance switches are closed and power is present at the line terminals of:
- Blower motor starter
- Oil pump motor starter (if provided).

The sequences do not attempt to correlate the action of the fuel supply system or feedwater system except for the interlock controls that directly relate to the action of the program relay. Chapters 5 and 6 contain operating instructions and specific information on setting and adjusting the controls.

B. CIRCUIT AND INTERLOCK CONTROLS

The burner control circuit is a two-wire system designed for 115 Vac, 60 Hz, single-phase power.

The electrical portion of the boiler is made up of individual circuits with controls that are wired in a manner designed to provide a safe workable system. The program relay provides connection points for the interconnection of the various circuits.

The controls used vary depending upon the fuel oil or gas and the specific requirement of applicable regulatory bodies. Refer to the boiler wiring diagram to determine the actual controls provided. The circuits and controls normally used in the circuits follow and are referred to in the following sequence of operation.

Notice

The make or model of the program relay provided will vary depending upon job specifications. The following sequence applies regardless of the make or model. Please refer to the Wiring Diagram (WD) prepared by Cleaver-Brooks for your specific installation.

Limit Circuit:

- Burner switch (BS)
- Operating limit control (OLC) - pressure or temperature
- High limit control (HLC) - pressure or temperature
- Low-water cutoff (LWCO)
- Gas-oil selector switch (GOS) - (Combination burner only)
- Low gas pressures switch (LGPS)
- High gas pressure switch (HGPS)

Fuel valve interlock circuit

- Main gas valve auxiliary switch (MGVAS)
- Oil valve auxiliary switch (OVAS)

Blower Motor Starter Circuit

- Blower motor starter (BMS)

Running Interlock Circuit

- Blower motor starter interlock (BMSI)
- Combustion air proving switch (CAPS)

Low Fire Proving Circuit

- Low fire switch (LFS)

Pilot Ignition Circuit

- Gas pilot valve (GPV)
- Ignition transformer (IT)
- Gas pilot vent valve (GPVV) (if provided)

Flame Detector Circuit

- Flame detector (FD)
- Main fuel valve circuit
- Main gas valve (MGV)
- Main gas vent valve (MGVV) (if provided)
- Oil valve (OV)
- Main fuel valve light (FVL)

Firing Rate Circuit

- Damper motor transformer (DMT)
- Modulating damper motor (MDM)
- Manual-automatic switch (MAS)

- Manual flame control (MFC)
- Modulating control (MC)

To comply with requirements of insurance underwriters such as Factory Mutual (FM), Industrial Risk Insurers (IRI) or others, additional interlock devices may be used in addition to the circuits mentioned in Section B.

High Fire Proving Circuit

- High fire switch (HFS)

Running Interlock and Limit Circuit

- Low oil pressure switch (LOPS)
- High oil pressure switch (HOPS)
- Auxiliary low-water cutoff (ALWCO)

Pilot Lights and Alarm Circuit

Indicator lights provide visual information on the operation of the boiler as follows:

- Flame Failure
- Load Demand
- Fuel Valve (valve open)
- Low Water

In addition, an alarm bell is provided to ring under conditions of flame failure or low water.

The load demand light glows during the period that the unit is operating. When the operating limit control opens and the burner proceeds into a normal shutdown, the circuit to the load demand light is broken and the light extinguished.

The fuel valve light glows whenever the main fuel valves — oil or gas — are energized. It does not indicate the operation of the gas pilot valve.

The low water light glows whenever boiler water is below normal operating level. This condition also energizes an alarm relay, causing the alarm bell to sound to audibly notify the operator.

The flame failure light is energized from terminal 9 of the programmer control and glows whenever a safety lockout of the control occurs. This would be upon failure to ignite the pilot, upon failure to light the main flame or upon loss of flame. The alarm bell also rings. The safety switch must be manually reset to extinguish the light and silence the alarm

C. SEQUENCE OF OPERATION - OIL OR GAS

On a combination fuel unit, the gas/oil switch must be set for the proper fuel.

The following sequence occurs with power present at the program relay (PR) input terminals and with all other operating conditions satisfied.

Pre-Purge Cycle - When the burner switch (BS) is turned “on,” and controls wired in the “limit” and “fuel valve interlock” circuits are closed and no flame signal is present, the “blower motor start circuit” is powered energizing the blower motor starter (BMS). The load demand light (LDL) turns on.

At the same time, the program relay signals the modulating damper motor (MDM) to open the air damper. The damper begins to open and drives to its full open or high fire position. Opening the damper motor allows a flow of purging air through the boiler prior to the ignition cycle.

On certain boilers the circuitry will include a high fire switch (HFS). The purpose of the switch is to prove that the modulating damper motor (MDM) has driven the damper to the open position during the pre-purge cycle. In this instance, the “high fire proving circuit” is utilized.

The controls wired into the “running interlock circuit” must be closed within 10 seconds after the start sequence. In the event any of the controls are not closed at this time, or if they subsequently open, the program relay will go into a safety shutdown.

At the completion of the high fire purge period, the program relay signals the modulating damper motor (MDM) to drive the air damper to its low fire position.

To assure that the system is in low fire position prior to ignition, the low fire switch (LFS) must be closed to complete the “low fire proving circuit.” The sequence will stop and hold until the modulating damper motor (MDM) has returned to the low fire position and the contacts of the low fire switch (LFS) are closed. Once the low fire switch is closed, the sequence is allowed to continue.

Ignition Cycle - The ignition transformer (IT) and gas pilot valve (GPV) are energized from the appropriate pilot ignition terminal.

Caution

The cause for loss of flame or any other unusual condition must be investigated and corrected before attempting to restart.

Notice

The ignition trial cannot be started if flame or a flame simulating condition is sensed during the pre-purge period. A safety shutdown will occur if flame is sensed at this time.

Notice

An oil-fired burner may be equipped with a direct spark rather than a gas pilot. The ignition sequence of both is identical.

Notice

Depending upon the requirements of the regulatory body, insurer or fuel being burned, either the 10 or 15 second pilot ignition terminal may be used. Both provide the same function but differ in time interval allowed for proving main flame ignition. Refer to the boiler wiring diagram.

 Warning

The cause for loss of flame or any other unusual condition should be investigated and corrected before attempting to restart. Failure to follow these instructions could result in serious personal injury or death

The pilot flame must be established and proven by the flame detector (FD) within a 10 second period in order for the ignition cycle to continue. If for any reason this does not happen, the system will shut down and safety lockout will occur.

With a proven pilot, the main fuel valve(s) (OV or MGTV) is energized and the main fuel valve light (FVL) in the panel is lighted. The main flame is ignited and the trial period for proving the main flame begins. It lasts 10 seconds for light oil and natural gas. At the end of the proving period, if the flame detector still detects main flame, the ignition transformer and pilot valve are deenergized and pilot flame is extinguished.

Note: If the main flame does not light, or stay lit, the fuel valve will close. The safety switch will trip to lock out the control. Refer to flame loss sequence (section D) for description of action.

Run Cycle - With main flame established, the program relay releases the modulating damper motor (MDM) from its low fire position to control by either the manual flame control (MFC) or the modulating control (MC), depending upon the position of the manual-automatic switch (MAS). This allows operation in ranges above low fire.

With the manual-automatic switch (MAS) set at automatic, subsequent modulated firing will be at the command of the modulating control (MC), which governs the position of the modulating damper motor (MDM). The air damper and fuel valves are actuated by the motor through a linkage and cam assembly to provide modulated firing rates.

Note: Normal operation of the burner should be with the manual-automatic switch in the automatic position and under the direction of the modulating control. The manual position is provided for initial adjustment of the burner over the entire firing range. When a shutdown occurs while operating in the manual position at other than low fire, the damper will not be in a closed position, thus allowing more air than desired to flow through the boiler. Excess air flow subjects the pressure vessel metal and refractory to undesirable conditions.

The burner starting cycle is now complete. The (LDL) and (FVL) lights on the panel remain lit. Demand firing continues as required by load conditions.

Burner Shutdown-Post Purge - The burner will fire until steam pressure or water temperature in excess of demand is generated. With modulated firing, the modulating damper motor (MDM) should return to the low fire position before the

operating limit control (OLC) opens. When the limit control circuit is opened, the following sequence occurs:

The main fuel valve circuit is deenergized, causing the main fuel valve (MGV) or (OV) to close. The flame is extinguished. The control panel lights (LDL) and (FVL) are turned off. The blower motor continues to run to force air through the boiler for the post purge period.

The blower motor start circuit is deenergized at the end of the post purge cycle and the shutdown cycle is complete.

The program relay is now ready for subsequent recycling, and when steam pressure or water temperature drops to close the contacts of the operating control, the burner again goes through its normal starting and operating cycle.

D. FLAME LOSS SEQUENCE

The program relay will recycle automatically each time the operating control closes, or after a power failure. It will lockout following a safety shutdown caused by failure to ignite the pilot, or the main flame, or by loss of flame. Lockout will also occur if flame or flame simulating condition occurs during the prepurge period.

The control will prevent start-up or ignition if limit circuit controls or fuel valve interlocks are open. The control will lock out upon any abnormal condition affecting air supervisory controls wired in the running interlock circuit.

1. No pilot flame.

The pilot flame must be ignited and proven within a 10-second period after the ignition cycle begins. If not proven within this period, the main fuel valve circuit will not be powered and the fuel valve(s) will not be energized. The ignition circuit is immediately deenergized and the pilot valve closes, the reset switch lights and lockout occurs immediately.

The blower motor will continue to operate. The flame failure light and the alarm bell (optional) are energized 10 seconds later.

The blower motor will be deenergized. The lockout switch must be manually reset before operation can be resumed. (Refer to the previous caution.)

2. Pilot but no main flame.

When the pilot flame is proven, the main fuel valve circuit is energized. Depending upon the length of the trial-for-ignition period, the pilot flame will be extinguished 10 or 15 seconds later. The flame detecting circuit will respond to deenergize the main fuel valve circuit within 2 to 4 seconds to stop the flow of fuel. The reset switch lights and lockout occurs immediately. The blower motor will continue to operate.

Caution

The lockout switch must be manually reset following a safety shutdown. The cause for loss of flame or any unusual condition should be investigated and corrected before attempting to restart. Failure to follow these instructions could cause damage to the equipment.

The flame failure light and alarm bell (optional) are energized 10 seconds later.

The blower motor will be then deenergized. The lockout switch must be manually reset before operation can be resumed. (Refer to the previous caution.)

3. Loss of flame.

If a flame outage occurs during normal operation and/or the flame is no longer sensed by the detector, the flame relay will trip within 2 to 4 seconds to deenergize the fuel valve circuit and shut off the fuel flow. The reset switch lights and lockout occurs immediately. The blower motor continues operation. The flame failure light and alarm bell (optional) are energized 10 seconds later.

The blower motor will be deenergized. The lockout switch must be manually reset before operation can be resumed. (Refer to the previous caution.)

If the burner will not start, or upon a safety lockout, the trouble shooting section in the operating manual and the technical bulletin should be referred to for assistance in pinpointing problems that may not be readily apparent.

The program relay has the capability to self-diagnose and to display a code or message that indicates the failure condition. Refer to the control bulletin for specifics and suggested remedies. Familiarity with the program relay and other controls in the system can be obtained by studying the contents of the manual and this bulletin.

Knowledge of the system and its controls will make troubleshooting much easier. Costly down time or delays can be prevented by systematic checks of the actual operation against the normal sequence to determine the stage at which performance deviates from normal. Following a routine may possibly eliminate overlooking an obvious condition, often one that is relatively simple to correct.

Remember, a safety device, for the most part, is doing its job when it shuts down or refuses to operate. Never attempt to circumvent any of the safety features.

Preventive maintenance and scheduled inspection of all components should be followed. Periodic checking of the relay is recommended to see that a safety lockout will occur under conditions of failure to ignite either pilot or main flame, or from loss of flame.

MNEMONIC	DESCRIPTION
A	
A	Amber (Color Of Pilot Light)
AAFL	Atomizing Air Failure Light
AAFR	Atomizing Air Failure Relay
AAPL	Atomizing Air Proven Light
AAPS	Atomizing Air Proving Switch
AAPS-B	Atomizing Air Proving Switch- Burner
AAPS-C	Atomizing Air Proving Switch- Compressor
AASS	Atomizing Air Selector Switch
AB	Alarm Bell
ACCR	Air Compressor Control Relay
ACM	Air Compressor Motor
ACMCB	Air Compressor Motor Circuit Breaker
ACMF	Air Compressor Motor Fuses
ACMS	Air Compressor Motor Starter
ACMSI	Air Compressor Motor Starter Interlock
AH	Alarm Horn
ALFR	Assured Low Fire Relay
ALWCO	Auxiliary Low Water Cutoff
AM	Ammeter
AMS	Atomizing Media Switch
AOV	Auxiliary Oil Valve
APR	Air Purge Relay
APV	Air Purge Valve
AR	Alarm Relay
AS	Auxiliary Switch (Suffix)
ASR	Alarm Silencing Relay
ASS	Alarm Silencing Switch
ASV	Atomizing Steam Valve
AT	Annunciator Transformer
AWCBDS	Auxiliary Water Column Blowdown Switch
B	
B	Blue (Color of Pilot Light)
BC	Bias Control
BDCS	Breeching Damper Closed Switch
BDOS	Breeching Damper Open Switch
BDRS	Blowdown/Reset Switch
BFPL	Boiler Feed Pump Light
BFBM	Boiler Feed Pump Motor
BFBMCB	Boiler Feed Pump Motor Circuit Breaker
BFBPMF	Boiler Feed Pump Motor Fuses
BFBPMS	Boiler Feed Pump Motor Starter
BFPS	Boiler Feed Pump Switch
BFTS	Back Flow Temperature Switch
BHS	Boiler - Header Switch
BIOL	Boiler in Operation Light
BIOR	Boiler In Operation Relay
BM	Blower Motor
BMCB	Blower Motor Circuit Breaker
BMCR	Blower Motor Control Relay
BMF	Blower Motor Fuses
BMPR	Blower Motor Power Relay
BMPs	Blower Motor Purge Switch
BMR	Blower Motor Relay
BMS	Blower Motor Starter

MNEMONIC	DESCRIPTION
BMSI	Blower Motor Starter Interlock
BMSS	Boiler Master Selector Switch
BS	Burner Switch
BSS	Boiler Selector Switch
BWPM	Booster Water Pump Motor
BWT	Booster Water Thermostat
C	
CAFL	Combustion Air Failure Light
CAFR	Combustion Air Failure Relay
CAP	Capacitor
CAPS	Combustion Air Proving Switch
CCCB	Control Circuit - Circuit Breaker
CCF	Control Circuit Fuse
CCRS	Control Circuit Reset Switch
CCT	Control Circuit Transformer
CIPL	Changeover In Progress Light
CL	Canopy Light
CLS	Canopy Light Switch
COPS	Changeover Pressure Switch
COR	Changeover Relay
COTD	Changeover Time Delay
CPOL	Control Power on Light
CR	Control Relay
CSSS	Control System Selector Switch
CWPM	Circulating Water Pump Motor
CWPMCB	Circulating Water Pump Motor Circuit Breaker
CWPMF	Circulating Water Pump Motor Fuses
CWPMS	Circulating Water Pump Motor Starter
CWPMSI	Circulating Water Pump Motor Starter Interlock
CWPR	Circulating Water Pump Relay
CWPS	Circulating Water Pump Switch
CWSV	Cooling Water Solenoid Valve
D	
D	Denotes Digester Gas Equipment (Prefix)
DCVM	Direct Current Voltmeter
DG	Draft Gauge
DGHPV	Digester Gas Housing Purge Valve
DHWC	Deaerator High Water Control
DHWL	Deaerator High Water Light
DHWR	Deaerator High Water Relay
DISC	Disconnect (Entrance Switch)
DLWC	Deaerator Low Water Control
DLWL	Deaerator Low Water Light
DLWR	Deaerator Low Water Relay
DM	Damper Motor
DMT	Damper Motor Transformer
DNS	Day-Night Switch
DODE	Delay On Deenergization (Timer)
DOE	Delay On Energization (Timer)
DPS	Damper Positioning Switch
DS	Door Switch
E	
EDS	Emergency Door Switch
ESS	Emergency Stop Switch
ETM	Elapsed Time Meter
F	
FADM	Fresh Air Damper Motor

MNEMONIC	DESCRIPTION
FADR	Fresh Air Damper Relay
FD	Flame Detector
FDJB	Flame Detector Junction Box
FDPS	Flow Differential Pressure Switch
FFA	Flame Failure Alarm
FFL	Flame Failure Light
FFR	Flame Failure Relay
FGR	Flue Gas Recirculation
FGRCDTD	Flue Gas Recirculation Cool Down Time Delay
FGRCPSS	Flue Gas Recirculation Cam Position Switch
FGRFM	Flue Gas Recirculation Fan Motor
FGRFMS	Flue Gas Recirculation Fan Motor Starter
FGRFMSI	Flue Gas Recirculation Fan Motor Starter Interlock
FGRMVLS	Flue Gas Recirculation Manual Valve Limit Switch
FGRTD	Flue Gas Recirculation Time Delay
FORS	First Out Reset Switch
FPM	Feed Pump Motor
FPMS	Feed Pump Motor Starter
FPR	Feed Pump Relay
FPS	Feed Pump Switch
FRI	Firing Rate Interface
FRP	Firing Rate Potentiometer (O2 Trim)
FS	Flow Switch
FSS	Fuel Selector Switch
FSSM	Flame Signal Strength Meter
FVEL	Fuel Valve Energized Light
FVL	Fuel Valve Light
FVR	Fuel Valve Relay
FWC	Feed Water Control
FWVT	Feed Water Valve Transformer
G	
G	Green (Color Of Pilot Light)
GGL	Gauge Glass Light
GOL	Gas Operation Light
GOR	Gas-Oil Relay
GOS	Gas-Oil Switch
GOR	Gas-Oil Relay
GPS	Gas Pressure Sensor
GPV	Gas Pilot Valve
GPVV	Gas Pilot Vent Valve
GR	Gas Relay
GSSV	Gas Sensor Solenoid Valve
GVEL	Gas Valve Energized Light
GVTS	Gas Valve Test Switch
H	
HATC	High Ambient Temperature Control
HBWTC	High Boiler Water Temperature Control
HBWTL	High Boiler Water Temperature Light
HFAV	High Fire Air Valve
HFGV	High Fire Gas Valve
HFL	High Fire Light
HFOV	High Fire Oil Valve
HFPS	High Furnace Pressure Switch
HFS	High Fire Switch
HFS-A	High Fire Switch - Air
HGPL	High Gas Pressure Light
HGPR	High Gas Pressure Relay

MNEMONIC	DESCRIPTION
HGPS	High Gas Pressure Switch
HHFL	Header High Fire Light
H/LWA	High Low Water Alarm
HLC	High Limit Control
HLFC	High-Low Fire Control
HLPC	High Limit Pressure Control
HLTC	High Limit Temperature Control
HMC	Header Modulating Control
HOPL	High Oil Pressure Light
HOPR	High Oil Pressure Relay
HOPS	High Oil Pressure Switch
HOLC	Header Operating Limit Control
HOTL	High Oil Temperature Light
HOTR	High Oil Temperature Relay
HOTS	High Oil Temperature Switch
HPCO	High Pressure Cutoff
HSPC	High Steam Pressure Control
HSPL	High Steam Pressure Light
HSPR	High Steam Pressure Relay
HSTC	High Stack Temperature Control
HSTL	High Stack Temperature Light
HSTS	High Stack Temperature Switch
HWAR	High Water Alarm Relay
HWC	High Water Control
HWCO	High Water Cutoff
HWL	High Water Light
I	
(I.C.)	Instantaneously Closed
(I.O.)	Instantaneously Open
IL	Ignition Light
INT	Interval (Timer)
IR	Ignition Relay
IT	Ignition Transformer
J	
JPP	Jackshaft Position Potentiometer
L	
LAMPS	Low Atomizing Media Pressure Switch
LASPS	Low Atomizing Steam Pressure Switch
LDL	Load Demand Light
LDPS	Low Differential Pressure Switch
LDS	Low Draft Switch
LFAV	Low Fire Air Valve
LFGV	Low Fire Gas Valve
LFHTD	Low Fire Hold Time Delay
LFL	Low Fire Light
LFOV	Low Fire Oil Valve
LFPS	Low Fire Pressure Switch
LFR	Low Fire Relay
LFS	Low Fire Switch
LFS-A	Low Fire Switch - Air
LFS-F	Low Fire Switch - Fuel
LFS-G	Low Fire Switch - Gas
LFS-O	Low Fire Switch - Oil
LFTC	Low Fire Temperature Control
LGPL	Low Gas Pressure Light
LGPR	Low Gas Pressure Relay
LGPS	Low Gas Pressure Switch

MNEMONIC	DESCRIPTION
LIAPS	Low Instrument Air Pressure Switch
LLPC	Low Limit Pressure Control
LLPR	Low Limit Pressure Relay
LLR	Lead Lag Relay
LLTC	Low Limit Temperature Control
LLTR	Low Limit Temperature Relay
LOPL	Low Oil Pressure Light
LOPR	Low Oil Pressure Relay
LOPS	Low Oil Pressure Switch
LOTL	Low Oil Temperature Light
LOTR	Low Oil Temperature Relay
LOTS	Low Oil Temperature Switch
LPAPS	Low Plant Air Pressure Switch
LPCO	Low Pressure Cutoff
LPS	Low Pressure Switch
LSPAR	Low Steam Pressure Alarm Relay
LSPC	Low Steam Pressure Control
LSPL	Low Steam Pressure Light
LSPR	Low Steam Pressure Relay
LSPS	Low Steam Pressure Switch
LTS	Lamp Test Switch
LWA	Low Water Alarm
LWAR	Low Water Alarm Relay
LWCO	Low Water Cutoff
LWFL	Low Water Flow Light
LWL	Low Water Light
LWR	Low Water Relay
LWRR	Low Water Reset Relay
M	
MA	Milli-amp
MAS	Manual - Automatic Switch
MAM	Micrometer
MC	Modulating Control
MCS	Manual Control Switch
MDM	Modulating Damper Motor
MDMAS	Modulating Damper Motor Auxiliary Switch
MFC	Manual Flame Control (Potentiometer)
MFGRTS	Minimum Flue Gas Recirculation Temperature Switch
MFVL	Main Fuel Valve Light
MFVV	Motorized Feed Water Valve
MGV	Main Gas Valve
MGVAS	Main Gas Valve Auxiliary Switch
MGVEL	Main Gas Valve Energized Light
MGVV	Main Gas Vent Valve
MLC	Modulating Level Control
(MOM)	Momentary
MOV	Main Oil Valve
MOVAS	Main Oil Valve Auxiliary Switch
MOVEL	Main Oil Valve Energized Light
MPC	Modulating Pressure Control
MPCB	Main Power Circuit Breaker
MPP	Manual Positioning Potentiometer
(MR)	Manual Reset
MTC	Modulating Temperature Control
MVA	Make-Up Valve Actuator
N	
N	Denotes Natural Gas Equipment (Prefix)

MNEMONIC	DESCRIPTION
(N.C.)	Normally Closed
(N.O.)	Normally Open
NFL	No Flow Light
NFR	No Flow Relay
NGHPV	Natural Gas Housing Purge Valve
O	
ODA	Outlet Damper Actuator
ODM	Outlet Damper Motor
ODMAS	Outlet Damper Motor Auxiliary Switch
ODMT	Outlet Damper Motor Transformer
ODS	Oil Drawer Switch
OH	Oil Heater
OHCB	Oil Heater Circuit Breaker
OHF	Oil Heater Fuses
OHR	Oil Heater Relay
OHS	Oil Heater Switch
OHT	Oil Heater Thermostat
OLC	Operating Limit Control
OLPC	Operating Limit Pressure Control
OL'S	Thermal Overloads
OLTC	Operating Limit Temperature Control
OMPM	Oil Metering Pump Motor
OMPMF	Oil Metering Pump Motor Fuse
OOL	Oil Operation Light
OPM	Oil Pump Motor
OPMCB	Oil Pump Motor Circuit Breaker
OPMF	Oil Pump Motor Fuses
OPMS	Oil Pump Motor Starter
OPPM	Oil Purge Pump Motor
OPR	Oil Purge Relay
OPRL	Oil Pump Running Light
OPRS	Oil Pressure Sensor
OPS	Oil Pump Switch
OPSPM	Oil Pump Supply Pump Motor
OPV	Oil Purge Valve
OR	Oil Relay
ORV	Oil Return Valve
OSOV	Oil Shutoff Valve
OSPS	O2 Set Point Switch
OSS	Oil Selector Switch
OT	Outdoor Thermostat
OTS	Oil Temperature Sensor
OV	Oil Valve
OVAS	Oil Valve Auxiliary Switch
OVEL	Oil Valve Energized Light
P	
P	Denotes Propane Gas Equipment (Prefix)
PAASV	Plant Air Atomizing Solenoid Valve
PAPS	Purge Air Proving Switch
PC	Pump Control
PCL	Purge Complete Light
PCR	Pump Control Relay
PFCC	Power Factor Correction Capacitor
PFFL	Pilot Flame Failure Light
PFFR	Pilot Flame Failure Relay
PFPS	Positive Furnace Pressure Switch
PHGPS	Pilot High Gas Pressure Switch

MNEMONIC	DESCRIPTION
PIPL	Purge in Progress Light
PIS	Pilot Ignition Switch
PLC	Programmable Logic Controller
PLGPS	Pilot Low Gas Pressure Switch
POL	Power On Light
POV	Pilot Oil Valve
PPL	Pre-Purging Light
PPR	Post Purge Relay
PPTD	Post Purge Time Delay
PR	Program Relay
PRL	Purge Ready Light
PRPTD	Pre-Purge Time Delay
PR	Program Relay
PRPTD	Per-Purge Time Delay
PS	Power Supply
PSF	Power Supply Fuse
PSS	Pump Selector Switch
PSV	Purge Solenoid Valve
PT	Purge Timer
PTS	Pump Transfer Switch
PUCR	Purge Complete Relay
PUR	Purge Relay
R	
R	Red (Color of Pilot Light)
RAR	Remote Alarm Relay
RATD	Remote Alarm Time Delay
RES	Resistor
RML	Run Mode Light
RMR	Release To Modulate Relay
RS	Range Switch
RSR	Remote Start Relay
RTD	Resistance Temperature Detector
S	
SBFPL	Stand By Feed Pump Light
SBFPM	Stand By Feed Pump Motor
SBFPMCB	Stand By Feed Pump Motor Circuit Breaker
SBFPMF	Stand By Feed Pump Motor Fuses
SBFPMS	Stand By Feed Pump Motor Starter
SBOV	Surface Blow Off Valve
SBPS	Sootblower Pressure Switch
SBR	Sootblower Relay
SC	Scanner
SCTS	Supervisory Cock Test Switch
SDL	Steam Demand Light
SHT	Steam Heater Thermostat
SHV	Steam Heater Valve
SLCL	Safety Limits Complete Light
SPIR	System Pump Interlock Relay
SPS	Steam Pressure Sensor
SS	Selector Switch
SSC	Sequencing Step Controller
SSL	Safety Shutdown Light
SSR	Solid State Relay
SSV	SpanSolenoid Relay
STHWC	Surge Tank High Water Control
STHWL	Surge Tank High Water Light
STHWR	Surge Tank High Water Relay

MNEMONIC	DESCRIPTION
STLWC	Surge Tank Low Water Control
STLWL	Surge Tank Low Water Light
STLWR	Surge Tank Low Water Relay
T	
(T.C.)	Timed Closed
(T.O.)	Timed Open
TB	Terminal Block
T/C	Thermocouple
TC	Time Clock
TCR	Time Clock Relay
TD	Time Delay
TDAS	Time Delay Auxiliary Switch
TFWR	Transistorized Feedwater Relay
TPL	Transfer Pump Light
TPM	Transfer Pump Motor
TPMCB	Transfer Pump Motor Circuit Breaker
TPMF	Transfer Pump Motor Fuses
TPMS	Transfer Pump Motor Starter
TPS	Transfer Pump Switch
U	
UVFD	Ultra-Violet Flame Detector
V	
V	Voltmeter
VDR	Voltage Differential Relay
W	
W	White (Color of Pilot Light)
WC	Water Column
WCBDS	Water Column Blow Down Switch
WF	Water Feeder
WFNL	Water Flow Normal Light
WLC	Water Level Control
WO	Denotes Waste Oil Equipment (Prefix)
WTS	Water Temperature Sensor
Y	
Y	Yellow (Color of Pilot Light)



Section 5

Starting and Operating Instructions

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A. GENERAL PREPARATION FOR INITIAL STARTUP

Notice

If the boiler is not equipped with a ProFire burner. Please refer to the specific Operation and Maintenance manual for the burner supplied.

Warning

It is recommended that the starting instructions be read completely until they are thoroughly understood, before attempting to operate the boiler, rather than performing each operation as it is read for the first time. Failure to follow these instructions could result in serious personal injury or death.

Warning

Prior to firing a boiler, be sure that discharge piping from safety valves or relief valves, and discharge piping from all blowdown and drain valves, is piped to a SAFE point of discharge, so that emission of hot water or steam cannot possibly cause injury. Failure to follow these instructions could result in serious personal injury or death.

Instructions in Section 5 are all based upon installation being complete and all electrical, fuel, water and vent stack connections are made.

The operator should be familiar with the burner, boiler, and all controls and components. To quickly locate and identify the various controls and components mentioned in the following paragraphs, refer to the illustrations and the contents of Section 1, 2 and 3. Instructions for adjusting major components are given in Section 6 this should be reviewed prior to firing. The wiring diagram should also have been studied, along with the firing sequence outlined in Section 4.

Verify supply of fuel and proper voltage. Check for blown fuses, open circuit breakers, dropped out overloads, etc. Check reset of all starters and controls having manual reset features. Check the lockout switch on the programmer and reset if necessary.

The boiler should be filled with water to the proper operating level using water of ambient temperature. Be sure that treated feedwater is available and used. In heating applications, the entire system should be filled and vented. Refer to Section 3 for water requirements. On a steam boiler, open the vent valve to vent air displaced during filling. Leave the vent valve open until the escape of steam is noted after the burner is operating.

Check all linkage for full and free movement of the damper and metering valves and cams. The check can be done by loosening the linkage at the damper motor connecting arm and manipulating the linkage by hand.

Check for rotation of all motors by momentarily closing the motor starter or relay. The blower impeller rotation is counter-clockwise for the ProFire, when viewed from the motor side of the burner (see **Figure 5-1**).

1. Fuel Supply

Before initial startup, verify that all fuel connections are tight. Fuel supply lines should be securely connected, correctly supported, and leak tested.

The gas train for gas-fired, or combination gas/oil, burners is provided with the overall boiler package. Configuration of the appropriate gas train is based on minimum requirements established by Underwriter's Laboratories / Canadian Underwriter's Laboratories (UL/cUL) and the responsible insurance carrier if applicable.

The pilot gas train is supplied with the burner, and is factory-installed.

Notice

All work on the burner should be performed by qualified persons knowledgeable in safe practices and applicable codes. Wiring should be in accordance with the National Electrical Code (NEC).



Figure 5-1 Motor and Fan Rotation

Fuel oil piping for oil-fired systems: In this circuit, an oil supply line from the oil tank is connected to the inlet port of the oil pump, and an oil return line from the pump circulates excess oil from the pump back to the oil supply tank.

Cleaver-Brooks recommends that all oil firing burners be equipped with an oil strainer (if not included with the burner) to prevent particles from clogging the nozzle. It is essential to follow the strainer manufacturer's maintenance schedule to ensure proper filtration.

2. Control Settings

Inspect the operating limit control for proper setting.

- The pressure control of a steam boiler should be set slightly above the highest desired steam pressure, but at least 10% lower than the setting of the safety valve.

Inspect the high limit control for proper setting.

⚠ Caution

Oil circulation back to the tank is required at all times. Do not start the burner with closed stop valves in the return lines or serious damage will occur

ProFire TM Packaged Burner System									
Input Range Gamme De Puissance		Gas (CFH) Gaz (PCH)	Press. (in. WC) (po. col. d'eau)	Liquid (GPH) Fluide (GPH)	Press. (PSI) (LPC)				
Max.									
Min.									
Fuel Type Type de combustible	Heating Value Valeur calorifique		Overfire Draft (Max.) Tirage maximum dans le foyer (in. W.C.) (po. col. d'eau)						
Current Characteristics Caractéristiques Electriques									
Load Charge	HP	VOLTS	PH	HZ	AMPS	FUSE			
Main Circuit principal									
Control Circuit Circuit de controle									
Fan Motor Moteur du ventilateur									
Air Compressor Compresseur d'air									
Circulating Pump Pompe Circulant									
Oil Heater Chauffeur Huile									
Control Circuit Circuit de controle									
Transformer	PRIMARY						SECONDARY		

Cleaver-Brooks
DIVISION OF AQUASOL, INC., MILWAUKEE, WISCONSIN

Figure 5-2 Data Plate

Warning

Shut off and lock out all electrical power to the burner before performing any service or maintenance that requires removal of electrical equipment covers or component parts. Failure to follow these instructions could result in serious personal injury or death.

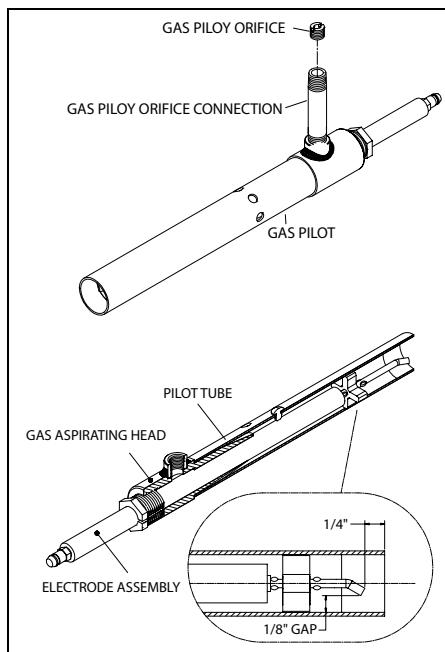


Figure 5-3 Gas Pilot

Before burner startup, the two oil solenoid valves are in the closed (de-energized) position and the oil metering valve is in its most open position. Under this condition (with the pump operating), oil cannot flow to the oil burner nozzle, but circulates through the by-pass tubing, oil metering valve, and back to the inlet of the pump. When the flame safeguard control calls for the main flame, the two oil solenoid valves are electrically energized. After opening, oil flows through the nozzle at the low-fire flow rate.

When high-fire operation is required, the modulating motor, by way of the valve linkage, rotates the oil metering valve to its least-open position. This reduces the flow rate of oil through the by-pass circuit, which increases the oil flow to the burner nozzle.

3. Electrical Requirements And Connections

Shut off and lock out all electrical power to the burner before performing any service or maintenance that requires removal of electrical equipment covers or component parts. Failure to follow these instructions could result in serious personal injury or death.

Verify that all electrical power supplies and branch circuit wiring are sized in accordance with the electrical loads shown on the specification plate on the side of the burner control cabinet (**Figure 5-2**). Check system interlocks, control interfaces, and any additional remote controls against the system schematic and wiring diagram. Refer to the Cleaver-Brooks wiring diagram supplied with the burner for specific requirements. Verify that all supply wiring terminations are tight.

4. Linkage Connections

Inspect all linkages for damage and/or loosening during shipment. All fasteners must be secure for safe operation. All connections must be correctly positioned and tightened. Apply a lock-tight type compound to any fasteners after adjustment.

5. Burner Settings

To ensure reliable and safe burner performance, the gas pilot assembly and gap setting of the electrode (**Figure 5-3**), and the relative positions of the burner nozzle, diffuser, and air baffle components must be correctly set (**Figure 5-3**). Normally these items are preset at the factory, but must be checked prior to placing the burner into initial service, or after conducting any service work that may have altered their positions.

1. Remove the nozzle/diffuser assembly as follows:
 - A. Lock out and tag the electrical power supply to the burner to prevent inadvertent operation during checkout or maintenance activities.
 - B. Disconnect the oil piping from the end of the blast tube.
 - C. Remove the fasteners that secure the nozzle/diffuser assembly to the top of the fan housing, and remove the nozzle/diffuser assembly from the burner.

Warning

Inadvertent burner operation can cause serious injury, or death. Do not perform maintenance on a burner without first disabling the electrical power supply. Lock out and tag the electrical power supply to prevent inadvertent burner startup during checkout or maintenance activities. Failure to follow these instructions could result in serious personal injury or death.

2. Refer to **Figure 5-4** and measure the distance from the tip of the nozzle to the diffuser. If necessary, adjust the position of the diffuser as follows:

- A. Loosen the locking screws on the diffuser clamp.
 - B. Slide the diffuser clamp along the length of the burner pipe until the correct dimension is achieved.
 - C. Tighten the diffuser clamp securely to the burner pipe. Apply a Lock-tight type compound to the screws before tightening.

3. Carefully install the adjusted nozzle/diffuser assembly into the burner. Then re-connect the oil supply and high-voltage power cable to the assembly.

4. The diffuser-to-air baffle dimension must now be checked and adjusted (see **Figure 5-4** for correct dimension). Check and adjust to **Figure 5-4** as follows:

- A. Open the burner mounting door on the boiler. Swing the burner out to expose the diffuser and air baffle.
- B. Measure the distance between the leading edge of the diffuser and the front face of the inner ring on the air baffle assembly.
- C. If adjustment is required, loosen the burner pipe locking setscrew (located on the rear cap at the top of the fan housing) and slide the burner pipe in or out to achieve the correct dimension.
- D. Tighten the oil pipe locking setscrew securely.
- E. Swing the burner and mounting door into the closed position on the boiler and fasten the door securely.

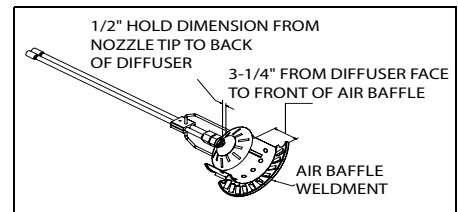


Figure 5-4 Drawer Assembly

B. STARTUP PROCEDURES

PRESTART TASKS AND CHECKLIST - ALL FUELS

Before proceeding with system startup and adjustment, be sure that overall installation is complete. Review the boiler operating and installation manual set carefully to verify that the boiler is properly set up for operation. Check that all shipped-loose items (those items not installed when shipped) have been correctly installed. Verify the supply of fuel. Check to make sure the burner is wired as shown on the wiring diagram. Ensure that all control wiring terminals are tight.

Complete the following checklist in preparation for system startup:

- Confirm that the fuel and electrical connections have been completed in accordance with the applicable codes and insurance requirements (if necessary), and that connections comply with the piping schematic and wiring diagram.
- Check the combustion air fan motor for correct rotational direction.
- Check that the boiler is filled with water to the proper level, and that all circulating pumps (hot water units) are correctly installed and operational.
- Verify that there is proper gas pressure at the gas train, if this is a gas or combination burner. See the burner specification plate (Figure 5-8) for minimum and maximum natural gas pressure requirements.
- For oil burners confirm that the oil tank is adequately filled with the correct grade of fuel oil, and that any isolation valves in the supply and return lines are open.
- Check that the flame safeguard has been properly installed inside the control panel.
- Provide the following test equipment on site:
 1. Combustion analyzer for O₂.
 2. U-tube manometer, or pressure gauge, to measure gas pressures (main and pilot).
 3. Inclined manometer to measure draft pressures.
 4. Smoke spot tester for oil fired units. CO analyzer for gas fired burners.
 5. Voltmeter.
 6. Thermometers and thermocouples.

AIR AND FUEL CONTROLS (DESCRIPTION)

The combustion system air and fuel controls have been factory adjusted, and the unit has been test fired before it was shipped. Regardless of preliminary adjustment and operation, it is necessary to readjust the controls for local conditions:

- The fuel flow controls must be adjusted to establish the rated heat input over the full range of firing-rate modulation.
- The air controls need to be adjusted, relative to the established fuel flow rates, to provide the correct amount of air for complete, efficient combustion.

Fuel and air adjustments are similar on all ProFire burners, whether gas-fired, oil-fired, or combination gas/oil fired. The following topics describe air and fuel flow rate adjustments, and the combustion set-point objectives for optimum combustion performance:

1. A. Air Flow Adjustments

The Profire burner includes a unique rotary air damper design with cam fuel trim. Fuel and air adjustments are similar on all Profire burners, whether gas-fired, oil-fired, or combination gas/oil fired. The following sections describe air and fuel flow rate adjustments, as well as the combustion set-point objectives for optimum combustion performance.

The modulating air damper regulates the flow of combustion air to the burner at flow rates corresponding to the maximum and minimum fuel input to the burner. The air damper and fuel valves are connected via linkages to a common modulating motor, or actuator. The travel, or stroke, of the rotary air damper should be checked to verify proper operation prior to any fuel adjustments. **Figure 5-6** shows the recommended linkage settings at the low fire start positions for each model burner.

Check the linkages to confirm they are securely fastened and ready for operation (see **Figure 5-7**). As mentioned previously, the linkages have been factory set and tested, although they may require minor adjustment after shipment. On combination gas-oil burners, the fuel selector switch should initially be set to the "GAS" position.

With the manual gas shut-off valve closed, start the burner so it will pre-purge. When the high fire switch is closed, switch the flame safety control to "CHECK" or "TEST". At this point, the air damper position at high fire can be checked.

First make sure that the damper is not making contact with the damper stop, located inside the air damper box. If it is, carefully loosen the set screws of the damper arm while holding the damper shaft steady (see **Figure 5-7**), then rotate the damper off the stop approximately 5 degrees. Retighten the damper arm set screws.

Warning

Attempting initial burner startup with insufficient knowledge of the equipment and startup procedures can result in serious damage to the equipment. The operator must be totally familiar with the entire startup and adjustment process before attempting to operate the burner. Failure to follow these instructions can result in serious personal injury or death.



Figure 5-5 Rotary air damper linkage at low fire position

The damper shaft slot should be in a near vertical position. The air damper can now be stroked for full modulation. Switch the flame safety control back to "RUN". The modulating motor should drive to the low fire position. Observe the air damper travel and adjust the linkage rod clamp if the air damper does not travel to the desired position (5 to 25 degrees open) at low fire -- depending on the burner model, fuel, and turndown -- to a full open position at high fire. If necessary, repeat until air damper strokes properly.

2. Combustion Settings

Fuel and air flow rates are individually adjusted at low fire, at high fire, and at each intermediate cam screw position to achieve rated heat input, firing rate turndown, optimum efficiency, safe operation, and the ability to cope with environmental changes (including air temperature, humidity, barometric pressure,) and fuel property changes. Adjustments may be required to meet certain environmental emissions criteria, such as NO_x or CO. Combustion adjustments also vary with specific system applications.

Turndown capability for oil is typically less than that for natural gas. Therefore, on combination fueled burners, gas turndown performance may be restricted (or determined) by the excess air levels set initially for oil combustion.

Two key components residing in flue gas are used to optimize combustion efficiency; excess air and unburned fuel. The system should be adjusted to the minimum excess air quantity that provides low levels of unburned fuel with sufficient remaining oxygen to cope with normal atmospheric and fuel related changes. Unburned fuel is measured as carbon monoxide (CO) when burning natural gas, and smoke spots when burning oil.

ProFire burners are capable of operating at CO levels of less than 50 ppm at all firing rates. The burner should be set-up and maintained to yield smoke spot levels less than a #2 spot (ASTM D2156 Shell-Bacharach Scale) to minimize soot build-up in the boiler.

C. BURNER ADJUSTMENTS, SINGLE FUEL NATURAL GAS

Note: The operator must consider and allow for normal variations in air and fuel, which would reduce the range of excessive oxygen in the flue gas accordingly.

Notice

The low fire position will be fine-tuned during combustion start-up.

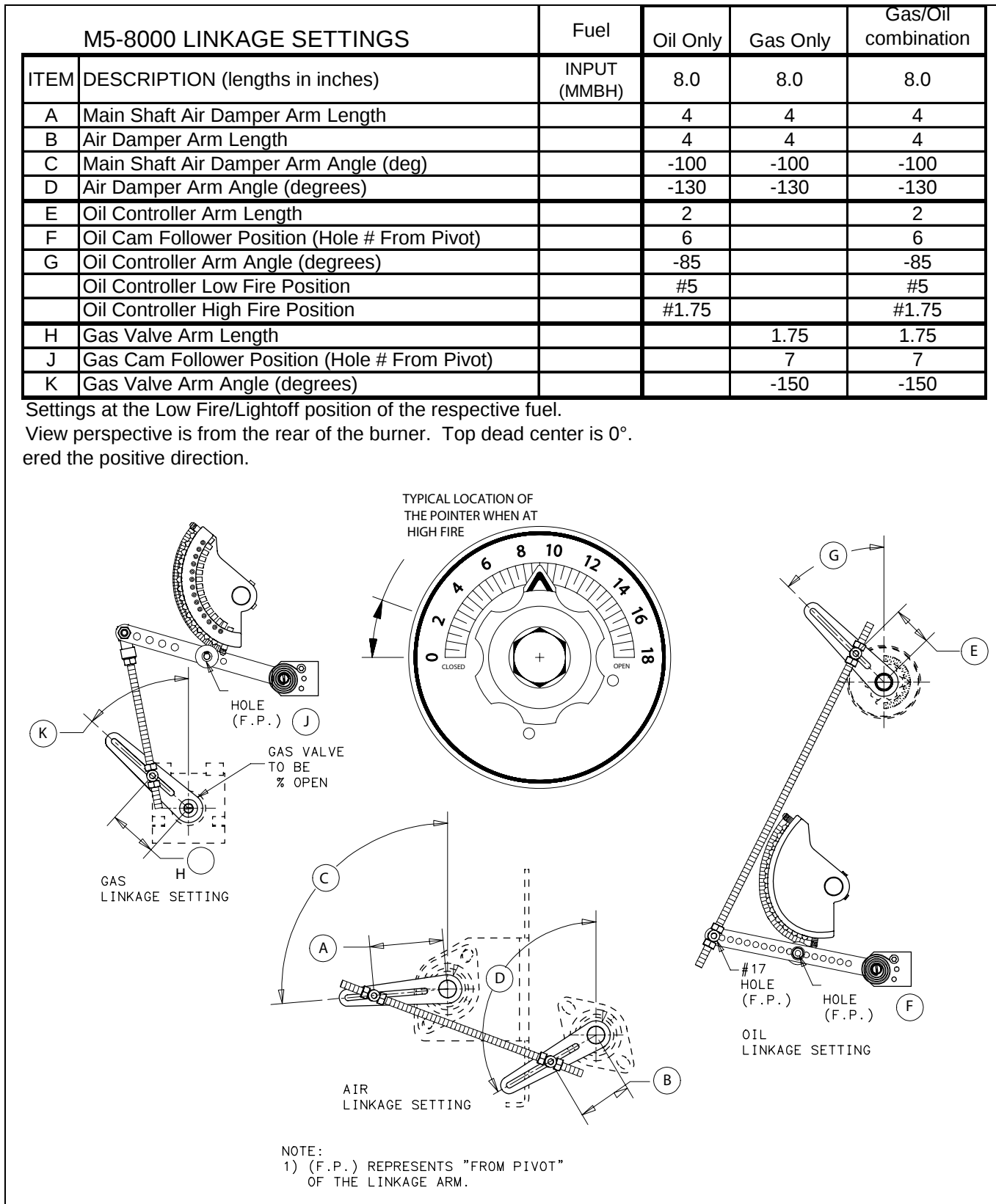


Figure 5-6 Initial Settings

 Warning

Attempting initial burner startup with insufficient knowledge of the equipment and startup procedures can result in serious damage to the equipment. The operator must be totally familiar with the entire startup and adjustment process before attempting to operate the burner. Failure to follow these instructions can result in serious personal injury or death

Notice

The linkages have been factory-set and tested, although they may require fine adjustment for the specific application. If the linkage is not in place, or if the setting has been lost, install the linkage in accordance with Figure 5-9.

Notice

For initial boiler startup, the downstream manual gas shutoff valve should be in the closed position to ensure proper operation of the automatic gas valves. This valve can then be slowly opened when the pilot is established and proven.

Note: This section provides detailed procedures for setup and adjustment of a gas-fired combustion system. Similar discussions are also presented in this chapter for startup and adjustment of oil-fired and combination-fueled gas or oil systems.

These procedures assume that the pre-startup tasks, checklists, and adjustments have been completed, and that the boiler system is prepared for initial startup. All necessary test equipment, should be available on site and installed.

CONTROLS SETUP. Complete the following burner system control setup steps before beginning the natural gas startup procedure:

1. Check the linkages to confirm they are securely fastened and ready for operation (**Figure 5-6**)
2. Set the burner switch in the "OFF" position.
3. Place the Manual/Auto mode switch to the "MANUAL" position.
4. Adjust the manual flame control to the "CLOSED" (or low fire) position.
5. Verify that the gas valve cam trim and linkage assembly is close to the settings listed in Table XX. Check that the cam follower, linkage and gas valve arm are in the proper positions and properly tightened. The slot in the gas valve shaft should be 5 to 10% open at the low fire position.

STARTUP. Proceed with startup of the natural gas-fired system as follows:

1. Close the downstream manual shut-off valve of the burner gas train.
2. Turn on electrical power for the burner, boiler, and related components.
3. Place the upstream manual gas valve in the on position, allowing natural gas to enter the gas train. (furthest from the burner). Reset Low Gas Pressure Switch (if applicable).
4. Verify that the gas metering valve is nearly closed.
5. Turn the burner switch on. This will start the combustion air fan motor and initiate the pre-purge sequence. Observe the travel of the gas valve. The valve should be nearly full open at the high fire position. If necessary, adjust the gas valve linkage rod clamp setting.
6. When the prepurge sequence ends, the pilot valve will open. The pilot flame should be visible from the viewing window.
7. When the pilot is established, the flame safeguard will energize the main gas valve (this is accompanied by fuel valve activity and illumination of the FUEL VALVE light). The main gas valve should be visually checked by observing the stem move from the CLOSED to the OPEN position. Slowly open the manual shut-off valve.

8. After the main flame has been established, the gas manifold pressure entering the burner should be measured using the pressure tap between the butterfly valve and the firing tube. This measurement should be compared to the Min. Gas Pressure value on the burner data plate. Obtain a stable operating point by adjusting the low fire cam screw to the recommended low fire pressure setting. (This low fire setting for startup is not critical; it is merely an acceptable starting point to begin the high fire fuel adjustment.)



Figure 5-7 Linkage Adjustment

9. After a few seconds, the oxygen (O₂) analyzer should have an accurate reading of the O₂ level in the flue gas. Normally, O₂ is set between 4 and 6 % at low fire, depending on the application and burner size. Adjust the low fire cam screw as needed to obtain a reasonable excess air level.
10. Operate the boiler at low fire until it is up to operating pressure (steam) or temperature (hot water). Then increase the fuel input to the boiler by turning the manual flame control potentiometer towards OPEN in small increments. This will cause the butterfly valve to open, allowing more gas into the burner. While increasing the input, observe that the O₂ levels remain within the safe firing range. Adjust the gas pressure regulator, as necessary, to correct this situation. Continue to do this until the burner reaches high fire (the potentiometer is at the open position).
11. Measure the gas manifold pressure at the high fire position. Adjust the high fire gas input with the pressure regulator to match the specified Max. Gas Pressure on the burner data plate. This value should correspond to the maximum rated fuel input to the burner

If a dedicated gas meter is available, the following formula may be used to check fuel flow. Conduct this measurement while operating at a constant rate.

Where:

HHV = The higher heating value of natural gas (1000 Btu/ft³). Contact your local gas company for an exact measurement.

P_{atm} = Atmospheric pressure in inches of mercury.

P_{gas} = Gas pressure ahead of the volumetric flow meter in inches of mercury.

T_{gas} = Gas temperature at the volumetric flow meter in °F.

RATE = Natural gas rate taken with the volumetric flow meter in ft³/second.

S = Seconds.

Notice

If the gas manifold pressure at low fire is significantly greater than the specified minimum, fine tuning of the low fire air damper setting is necessary to obtain proper turndown. First, reduce the gas manifold pressure to the specified minimum by adjusting the length of the gas valve cam link. Next, loosen the jam nuts on the air damper link, carefully close the damper to match the desired excess air level, and retighten the jam nuts. (This will have a very minimal effect on the high fire excess air.) Recheck the gas input rate or manifold pressure to verify minimum input.

Notice

Some meters may require 6.0 IN. H₂O correction to P_{gas} . Consult meter calibration data.

Warning

Do not tune the burner to a lower firing rate than the specified minimum values on the burner data plate. Input rates below the recommended minimum value can result in poor combustion and/or damage to burner firing tube components. Failure to follow these guidelines can result in unsafe operation of the burner leading to serious personal injury or death.

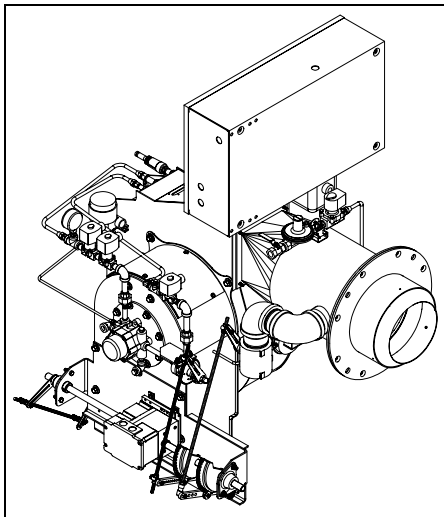


Figure 5-8 Combination Profile Burner

12. Fine-tune the high fire input with the corresponding high fire cam screw to obtain the desired excess air level. Normally, the O₂ level is set between 3.5 and 5 % at high fire, depending on the application and burner size..
13. Modulate the burner with the manual flame control to the next lower cam screw position. Measure the O₂ level and adjust the cam screw accordingly. Continue this procedure until the low fire cam screw is reached.
14. Check the gas manifold pressure (gas input rate as well if meter is available) against the burner data plate minimum settings. Adjust low fire cam screw accordingly.
15. Modulate the burner from low to high fire and back to low fire. Verify that combustion is stable and that the air damper and fuel valve are stroked properly and all linkages are tight.
16. When combustion tuning has been completed, install the brass cam locking set screws and tighten with sufficient torque to prevent unwanted changes of the cam screw settings during operation.

D. BURNER ADJUSTMENTS, SINGLE FUEL, OIL-FIRED (RETURN FLOW PRESSURE ATOMIZATION)

This section of the manual presents detailed procedures for initial startup of an oil-fired combustion system.

Note: The operator must consider and allow for normal variations in air and fuel, which would reduce the range of excessive oxygen in the flue gas accordingly.

This burner is designed to burn only those fuels shown on the burner data plate. Burning fuels not specified on the data plate could cause damage to the equipment.

The following procedures assume that the pre-startup tasks, checklists, and adjustments have been completed, and that the boiler system is prepared for initial startup. All necessary test equipment should be available on site.

Attempting initial burner startup with insufficient knowledge of the equipment and startup procedures can result in serious damage to the equipment. The operator must be totally familiar with the entire startup and adjustment process before attempting to operate the burner. Failure to follow these instructions could result in serious personal injury or death.

CONTROLS SETUP. Complete the following combination system control setup steps before beginning the oil-fired burner startup procedure:

1. Check the linkages to confirm that they are securely fastened and ready for operation (see **Figure 5-6**).

2. Place the burner switch to the OFF position.
3. Place the Manual/Auto mode switch to the MANUAL position.
4. Place the manual flame control potentiometer to the CLOSED (low-fire) position.
5. Verify that the oil metering valve, cam trim, and linkage assembly is close to the settings listed in Table XX. Check that the cam follower, linkage, oil metering valve arm and indicator are in the correct low fire positions and properly tightened. Two oil pressure gauges should be installed in the oil piping: the burner oil nozzle supply pressure is measured downstream of the oil safety shut-off valves while the nozzle return pressure is measured between the nozzle and the oil metering valve.
6. Open the manual shut-off valve of the gas pilot.

When a gas pilot is used, open the valve in the gas pilot line.

STARTUP. Proceed with initial startup of the oil-fired system as follows:

1. Turn on the electrical power for the burner, boiler, and related components.
2. Verify that the oil-metering valve is at the low fire start position.

Note: Opening the oil metering valve reduces oil flow to the burner.

3. Turn the burner switch on. This will start the blower motor and initiate the prepurge sequence. Observe the travel of the oil-metering valve. The valve should be nearly closed at the high fire position (see **Figure 5-6**). Check the specified high fire oil metering valve position in **Figure 5-6**. If necessary, adjust the oil valve linkage rod clamp setting.
4. When the prepurge sequence ends, the pilot valve will open. The pilot flame should be visible from the viewing window.
5. After the main flame has been established, the oil pressures entering and returning from the burner nozzle should be measured. On return flow pressure atomized oil systems, the supply pressure should remain relatively constant from low fire to high fire, normally between 270 and 300 psi. (The oil pump is factory set at 300 psi. If necessary, oil pump supply pressure can be adjusted with the pump's internal pressure regulating screw - see oil pump service bulletin for details.)
6. The low fire return pressure should match the Min. Oil Pressure specified on the burner data plate (between 40 - 100 psi). For fine-tuning, change the oil metering valve position by adjusting the low fire cam screw. If the pressure is significantly off, adjust the length of the oil cam linkage rod to correct the low fire position of oil metering valve. Adequate excess air should also be verified with an oxygen analyzer. Normally, O₂ is set

The linkages have been factory-set and tested, although they may require fine adjustment for the specific application. If the linkage is not in place, or if the setting has been lost, install the linkage in accordance with Figure 5-11.

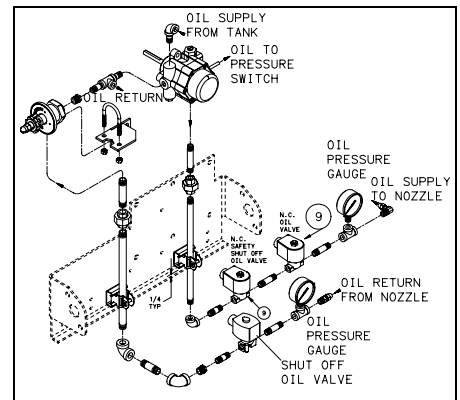


Figure 5-9 Oil Piping

Notice

If the pilot is established, the flame safeguard will energize the two oil solenoid valves (this is accompanied by a click from the solenoid valves and illumination of the FUEL VALVE light) and the oil burner should ignite on low-fire.

Notice

If the excess air significantly deviates from the recommended O₂ level after making the proper low fire oil valve adjustment, fine tuning of the low fire air damper setting is necessary to obtain proper turndown. Loosen the jam nuts on the air damper link, carefully adjust the damper to match the desired excess air level, and retighten the jam nuts. (This will have a very minimal effect on the high fire excess air.) Recheck the low fire oil return pressure to verify minimum input.

Notice

Burner input can be verified with the use of oil meters in the supply and return lines from the burner nozzle. The flow rate measured in the return line must be subtracted from the flow rate measured in the supply line. Following start-up, it is strongly recommended that the flow meters be removed from the system.

between 4 and 6 % at low fire, depending on the application and burner size.

7. Operate at low fire until it is thoroughly warmed. Then, one cam screw at a time, modulate to high fire with the manual flame control. This will cause the oil metering valve to close, resulting in an increase in the return line oil pressure. Check the excess air in the flue gas while modulating to high fire (maintain O₂ levels between 4 - 6 %). Make cam screw adjustments as needed to maintain adequate excess air.
8. Verify that the high fire supply pressure stays between 280 to 300 psi. (The oil pump is factory set at 300 psi. If necessary, oil pump supply pressure can be adjusted with the pump's internal pressure regulating screw - see oil pump service bulletin for details.)
9. Set the high fire oil return pressure to match the specified burner data plate Max. Oil Pressure setting (usually in the range of 160 - 220 psi) by adjusting the corresponding cam screw to open or close the oil-metering valve, as necessary.
10. Check the high fire excess air level. Normally, the O₂ level is set between 3.5 and 5 % at high fire, depending on the application and burner size.
11. Modulate the burner with the manual flame control to the next lower cam screw position. Measure the O₂ level at intermediate screw positions and adjust each cam screw to maintain between 3.5 to 5 %. Continue this procedure until the low fire cam screw is reached.
12. Verify that the low fire return oil pressure is at the burner data plate specified minimum pressure. Excess air level should be set between 4 to 6 % O₂. Fine tune by adjusting the low fire cam screw accordingly.
13. Following combustion setup, tighten all linkages. Check for smooth light off by cycling the burner through the pre-purge sequence again. During pre-purge, verify that all linkages, dampers and valves operate smoothly without interference or binding. Verify that the pilot flame is sufficient and the burner lights off smoothly.
14. Modulate and recheck combustion air at different firing rate positions. Smoke spot measurements should be less than a No. 2 (Bacharach).
15. When combustion tuning has been completed, install the brass cam locking set screws and tighten with sufficient torque to prevent unwanted changes of the cam screw settings during operation.

E. BURNER ADJUSTMENTS, COMBINATION GAS AND OIL

Note: The operator must consider and allow for normal variations in air and fuel, which would reduce the range of excessive oxygen in the flue gas accordingly.

This section of the manual presents procedures to be followed for initial startup of a combination ProFire burner.

These procedures assume that the pre-startup tasks, checklists, and adjustments have been completed, and that the boiler system is prepared for initial startup. All necessary test equipment should be available on site.

In general, the combination fueled system is to be started first using oil, because, as a fuel, oil has a greater combustion air requirement than natural gas. After being completely adjusted for oil combustion, the burner is re-started and adjusted using natural gas as fuel. Combustion adjustment of the combination burner for natural gas involves balancing the input gas rates only against the existing flow of combustion air, as established initially for oil-firing. Do not readjust the air shutters when tuning the combination burner for combustion of natural gas.

CONTROLS SETUP. Complete the following system control setup steps before beginning the combination burner startup procedure:

1. Check the linkages to confirm that they are securely fastened and ready for operation.

NOTE: The linkages have been factory-set and tested, although they may require fine tuning for the specific application. If the linkage is not in place, or if the setting has been lost, install the linkage in accordance with **Figure 5-6**.

2. Place the burner switch in the OFF position.
3. Place the Modulating Mode switch in the MANUAL position.
4. Place the manual flame potentiometer in the CLOSE (low-fire) position.
5. Verify that the oil metering valve, gas valve, cam trim and associated linkage assemblies are close to the settings listed in **Figure 5-6**. Check that the cam followers, linkages, valve arms and indicators are in the correct low fire positions and properly tightened. Two oil pressure gauges should be installed in the oil piping: the burner oil nozzle supply pressure is measured downstream of the oil safety shut-off valves while the nozzle return pressure is measured between the nozzle and the oil metering valve. The slot in the gas valve shaft should be 5 to 10% open at the low fire position.
6. Open the manual shut-off valve of the gas pilot.

STARTUP. Proceed with initial startup using oil as follows:

1. Position the fuel selector switch to "OIL".
2. Proceed with startup and combustion adjustments using the same procedures defined for oil-fired burners.

 Caution

This burner is designed to burn only those fuels shown on the burner data plate. Burning fuels not specified on the data plate could cause damage to the equipment.

 Warning

Attempting initial burner startup with insufficient knowledge of the equipment and startup procedures can result in serious damage. The operator must be totally familiar with the entire startup and adjustment process before attempting to operate the burner.

3. After the system has been completely adjusted for oil-firing, place the burner switch to the off position, and position the fuel selector switch to GAS.
4. Place the Manual/Auto mode switch to the MANUAL position.
5. Place the manual flame control potentiometer to the CLOSE (low-fire) position.
6. Close the downstream manual shutoff valve on the burner gas train (closest to the burner).
7. Admit natural gas to the gas train.
8. Verify that the butterfly valve is in a position that is nearly closed.
9. Proceed with startup and combustion adjustment procedures as described for gas-fired burners. Only adjustments to the gas valve linkage settings should be undertaken at this point. No adjustments should be made to the air damper linkage settings. Changes to the air damper settings could adversely effect oil combustion tuning.
10. When combustion tuning has been completed on both fuels, install the brass cam locking set screws and tighten with sufficient torque to prevent unwanted changes of the cam screw settings during operation.

Turn the burner switch on. This will start the blower motor and initiate the prepurge sequence.

When the prepurge sequence ends, the pilot valve will open. The pilot flame should be visible from the viewing window.

When the pilot is established, the flame safeguard will energize the main gas valve (this is accompanied by fuel valve activity and illumination of the FUEL VALVE light). The main gas valve should be visually checked by observing the stem move from the CLOSED to the OPEN position.

NOTE: The downstream manual gas shutoff valve should be in the closed position, for initial boiler startup, to ensure proper operation of the automatic gas valves. This valve can then be slowly opened when the pilot is established and proven.

After the main flame has been established, the gas pressure entering the burner should be read (using the pressure tap between the butterfly valve and the blast tube) to determine an initial estimate of the gas input rate. By doing so, and referring to [Figure 5-10](#), an approximation of the burner input can be assessed. Obtain a stable operating point by adjusting the butterfly valve to the pressure indicated in [Figure 5-10](#) and select the temporary firing rate. This rate for startup is not critical, but merely an acceptable starting point to begin the high fire adjustment procedures.

After a few seconds, the O₂ analyzer should have an accurate reading of the O₂ present in the flue gas. [Table 5-1](#) provides

a representation of the acceptable O₂ range for the gas burner. Normally, the O₂ levels are set between 3 and 5 percent at low fire, depending on the application and burner size (see the burner specification plate for the minimum firing rate).

Operate the boiler at low fire until it is thoroughly warmed. Then increase the fuel input to the boiler by turning the manual flame potentiometer towards open in small increments. This will cause the butterfly valve to open farther, allowing more gas into the burner. While increasing the input, observe that the O₂ levels remain within the range shown in **Table 5-1**. Adjust the gas pressure regulator, as necessary, to correct this situation. Continue to do this until the burner reaches high fire (the potentiometer is at the open position).

Adjust the high fire gas input to match the maximum rating. At high fire, the butterfly valve should be near the full open position (readjust linkage if required). Adjust the gas pressure to obtain the correct fuel input. (Maximum pressure specified on the burner specification plate.)

If a dedicated gas meter is available, the following formula may be used to check fuel flow. Conduct this measurement while operating at a constant rate.

NOTE: Some meters may require 6.0 IN. H₂O correction to P_{gas}. Consult meter calibration data.

Where:

HHV = The higher heating value of natural gas (1000 Btu/ft³). Contact your local gas company for an exact measurement.

P_{atm} = Atmospheric pressure in inches of mercury.

P_{gas} = Gas pressure ahead of the volumetric flow meter in inches of mercury.

T_{gas} = Gas temperature at the volumetric flow meter in °F.

RATE = Natural gas rate taken with the volumetric flow meter in ft³/second

S = Seconds.

NOTE: It is unnecessary to readjust the position of the high-fire or low-fire shutters after having been set for oil firing.

Modulate the burner to low fire. The butterfly valve should be adjusted to provide the correct fuel pressure at the low-fire position in accordance with the burner data plate minimum gas-pressure rating.

FUEL FLOW ADJUSTMENTS. Fuel flow rates are adjusted to provide the design-rated heat inputs into the burner at both high-fire (maximum rate) and low-fire (minimum rate) operating conditions. The maximum and minimum fuel input flow rates for the burner are identified on the data plate (see

Figure 5-8). Natural gas flow rates are specified in cfh (cubic feet per hour), and fuel oil flow rates are specified in gph (gallons per hour).

Fuel flow rate adjustment for both natural gas and oil is accomplished by regulating the fuel pressure against a fixed diameter orifice (nozzle). The methods for accomplishing the pressure regulation, however, are different for natural gas and oil.

The method for regulating the natural gas flow rate (manifold pressure) is as follows:

Maximum flow rate is established by operating the burner at high-fire with the butterfly valve fully open, then adjusting the manifold pressure to the maximum as specified on the data plate. Maximum manifold pressure is obtained by adjusting the main gas pressure regulator on the gas train while operating the burner at high-fire.

Gas flow modulation for turndown is accomplished by throttling the flow rate with the butterfly valve. The flow restriction of the partially closed butterfly valve reduces the flow of gas through the burner nozzle. The butterfly valve throttling position is controlled by linkage from the main air shutter shaft, which is operated by the modulating motor.

With the modulating motor positioned for low-fire operation, the butterfly valve linkage is adjusted to provide the minimum pressure in the nozzle manifold, as specified on the burner data plate.

The method for regulating the fuel-oil flow rate (nozzle pressure) is as follows:

Maximum flow rate is established by operating the burner at high-fire with the oil metering valve in a nearly closed position with the modulating motor set at the high-fire position. In this position, the flow of fuel oil through the oil by-pass is minimal, resulting in nearly maximum flow pressure from the pump. High-fire oil flow adjustment is accomplished by adjusting the linkage to the oil metering valve so that the burner nozzle pressure equals the maximum oil pressure specification on the burner data plate (see **Figure 5-8**).

Oil pressure modulation for turndown to low-fire operation is accomplished by increasing the flow rate of oil through the oil by-pass loop, which reduces pressure in the burner nozzle. This is accomplished by setting the modulating motor to the low-fire position, which causes the oil metering valve to open. While in this position, the oil metering valve linkage can be adjusted so that the burner nozzle pressure equals the minimum oil pressure specification on the burner specification plate (see **Figure 5-8**).

F. STARTUP, OPERATING AND SHUTDOWN - ALL FUELS

Depending upon the fuel being burned, the applicable previous sections in **Chapter 5** should be reviewed for preliminary instructions.

The fuel selector switch should be, accordingly, set to either oil or gas.

Set the manual-automatic switch (**Figure 2-1**) to “manual” and turn the manual flame control to “close.”

Turn burner switch to “ON.” The load demand light should glow. The low-water level light should remain out, indicating a safe water level in the boiler. The programmer is now sequencing. See Chapter 4 for sequence details.

On an initial starting attempt, several efforts might be required to accomplish “bleeding” of fuel lines, main or pilot. If ignition does not then occur, do not repeat unsuccessful attempts without rechecking the burner and pilot adjustment.

On ignition failure, the flame failure light will glow and the blower will purge the boiler of unburned fuel vapors before stopping. After ignition failure, wait a few moments before re-setting the lockout switch.

Do not re-light the pilot or attempt to start the main burner, either oil or gas, if the combustion chamber is hot and/or if gas or oil vapor combustion gases are present in the furnace or flue passages. Failure to follow these instructions could result in serious personal injury or death.

The burner and control system is designed to provide a “pre-purge” period of fan operation prior to establishing ignition spark and pilot flame. Do not attempt to alter the system or take any action that might circumvent the “pre-purge” feature. Failure to follow these instructions could result in serious personal injury or death.

After main flame ignition, the burner should be set on manual control at its low fire setting (that is, with manual flame control at “close”) until the boiler is properly warmed. In the case of a steam boiler, CLOSE THE VENT VALVE when the steam begins to appear.

A hot water boiler must have a continuous flow of system water through the vessel during the warm-up period. The entire water content of the system and boiler must be warmed prior to increasing fuel input.

If the flame at low fire provides insufficient heat to reach normal operating pressure or temperature after 30 minutes, gradually increase the firing rate by turning the manual

flame control in one point increments. Operate at the increased fuel input rate for a period of time until an increase is noted in pressure or temperature.

After the boiler is thoroughly warmed, turn the manual flame control to high fire. At this point a combustion analysis should be made, with instruments, and fuel flow regulated as required. Refer to the adjustment procedures in [Chapter 6](#). After making the high-fire adjustment, manually decrease the firing rate to analyze combustion gases, and adjust as required.

To properly perform the testing and adjusting, it is necessary that the burner be allowed to fire at a maximum rate long enough to achieve desired results.

Operating - Normal operation of the burner should be with the switch in the automatic position and under the direction of the modulating control. The manual position is provided for initial adjustment of the burner over the entire firing range. When a shutdown occurs while operating in the manual position at other than low fire, the damper will not be in a closed position, thus allowing more air than desired to flow through the boiler. The hot flame to cool air cycling subjects the pressure vessel metal and refractory to undesirable conditions.

With the switch set at “auto,” the burner will operate on a modulating basis according to the load demand.

The burner will continue to operate with modulated firing until the operating limit pressure or temperature is reached, unless:

The burner is manually turned “off.”

A low-water condition is detected by low-water level control.

The electrical or fuel supply is interrupted.

The combustion air pressure drops below minimum level.

There can be other reasons for shutdown such as motor overload, flame outages, tripped circuit breakers, blown fuses, or through other interlock devices in the circuitry.

When the burner is shut down normally, by either the operating limit control or by manually switching the burner off, the load demand light no longer glows.

Shutdown through conditions causing safety or interlock controls to open will actuate the flame failure light (and alarm if so equipped) and the load demand light will remain lit. The cause of this type of shutdown will have to be located, investigated, and corrected before operation can be resumed. Refer to the troubleshooting section in [Chapter 7](#).

Shutdown - When the operating limit control setting is reached to open the circuit or if the burner switch is turned “off,” the following sequence occurs.

The fuel valve is deenergized and the flame is extinguished. The timer begins operation and the blower motor continues running to force air through the furnace in the post-purge period.

At the end of the programmed post-purge period, the blower motor is turned off. The timer has returned to its original starting position and stops. The unit is ready to re-start.

It is advisable to check for tight shut-off of fuel valves. Despite precautions and strainers, foreign material in either new or renovated fuel lines may lodge under a valve seat and prevent tight closure. The situation is especially true in new installations. Promptly correct any conditions causing leakage. Failure to follow these instructions could result in serious personal injury or death

G. CONTROL OPERATIONAL TEST AND CHECKS

Proper operation of the various controls should be verified and tested when the boiler is initially placed into service, or whenever a control is replaced. Periodic checks should be made thereafter in accordance with a planned maintenance program.

The operating limit control may be checked by allowing steam pressure to increase until the burner shuts down. Depending upon the load, it may be necessary to manually increase the firing rate to raise steam pressure to the burner shut off point. If the load is heavy, the header valve can be closed or throttled until the pressure increases. Observe the steam gauge to check the cut off pressure as the operating limit control shuts the burner down. Slowly open the header valve to release steam pressure and check the cut-in setting as the burner restarts. Check the modulating control for the desired operating pressure range. See **Chapter 6** for instructions on the adjustment of controls.

The water temperature on a hot water boiler that may be operating at less than full load may be raised by manually increasing the firing rate until the burner shuts down through the action of the operating limit control. Observe the thermometer to verify the desired settings at the point of cut-out and again when the burner restarts. Return the manual automatic switch to “automatic” and check the modulating control for the desired temperature range. See Chapter 6 for instructions on the adjustment of the controls.

Check the proper operation and setting of the low-water cutoff and the auxiliary low water cutoff (and pump operating control, if used).

Proper operation of the flame failure device should be checked at startup and at least once a week thereafter. Refer

to **Chapter 8** for information on flame safety checks. Check the program relay's annunciation for any system failure. Observe the promptness of ignition of the pilot flame and the main flame.



Section 6

Adjustment and Maintenance

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A. GENERAL

While each boiler is tested for correct operation before shipment from the factory, variable conditions, such as burning characteristics of the fuel used and operating load conditions, require further adjustment after installation to assure maximum operating efficiency and economy. Prior to placing the boiler into initial service, a complete inspection should be made of all controls, connecting piping, wiring, and all fastenings such as nuts, bolts and setscrews to be sure that no damage or misadjustments occurred during shipment and installation.

A well planned maintenance program avoids unnecessary downtime or costly repairs, promotes safety and aids boiler code and local inspectors. An inspection schedule with a listing of procedures should be established. It is recommended that a boiler room log or record be maintained, recording daily, weekly, monthly and yearly maintenance activities. This provides a valuable guide and aids in obtaining economies and length of service from Cleaver-Brooks equipment.

Even though the boiler has electrical and mechanical devices that make it automatic or semi-automatic in operation, these devices require systematic and periodic maintenance. Any “automatic” features do not relieve the operator from responsibility, but rather free him of certain repetitive chores, providing him time to devote to upkeep and maintenance.

Good housekeeping helps maintain a professional appearing boiler room. Only trained and authorized personnel should be permitted to operate, adjust or repair the boiler and its related equipment. The boiler room should be kept free of all material and equipment not necessary to the operation of the boiler or heating system.

Alertness in recognizing an unusual noise, improper gauge reading, leaks, etc., can make the operator aware of an improper condition, permitting prompt corrective action that may prevent extensive repairs or unexpected downtime. Any steam, water or fuel leaks should be repaired as soon as they are noticed. Leaks are wasteful as well as hazardous. Include in the program preventive maintenance measures such as regularly checking the tightness of connections, locknuts, setscrews, packing glands, etc.

The air-fuel ratio should be checked often since this will alert the operator to losses in combustion efficiency which do not produce visible flame changes. Variations in fuel composition from one time to another may require readjustment of the burner. A combustion analyzer should be used to adjust fuel input for maximum operating efficiency and economy.

B. PERIODIC INSPECTION

Insurance regulations or local laws require a periodic inspection of the pressure vessel by an authorized inspector.

Section 3 contains information relative to this inspection.

Inspections of this type are usually, though not necessarily, scheduled for periods of normal boiler downtime such as an off-season. This major inspection can often be used to accomplish maintenance, replacements or repairs that cannot easily be done at other times. This also serves as a good basis for establishing a schedule for annual, monthly or other periodic maintenance programs.

While this inspection pertains primarily to the waterside and fireside surfaces of the pressure vessel, it provides the operator an excellent opportunity for detailed inspection of all components of the boiler including piping, valves, pumps, gaskets, refractory, etc. Comprehensive cleaning, spot painting or repainting and the replacement of expendable items should be planned for and taken care of during this time. Any major repairs or replacements that may be required should also, if possible, be coordinated with this period of boiler shutdown.

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

Cleaver-Brooks boilers are designed, engineered and built to give long life and excellent service on the job. Good operating practices and conscientious maintenance and care will obtain efficiency and economy from their operation and contribute to long years of performance.

C. WATER LEVEL CONTROLS AND WATERSIDE OF PRESSURE VESSEL

The need to periodically check water level controls and the waterside of the pressure vessel cannot be over-emphasized. Most instances of major boiler damage are the result of operating with low water or the use of untreated (or incorrectly treated) water.

Always be sure of the boiler water level. The water column should be blown down routinely. Check samples of boiler water and condensate in accordance with procedures recommended by your water consultant. Refer to **Section H** and **Section** in **Section3** for blowdown instructions and internal inspection procedures.

A typical water level control is mounted in the water column and has float actuated switches. One switch is connected to the burner limit circuit and will stop the burner if a low water condition occurs. On a steam boiler the other switch is connected to the feedwater circuit to energize a water pump or feeder valve to maintain water at the proper operating level.

Usually, the control is of the automatic reset type and will remake the limit circuit when the water level is restored. Some applications require that a control be equipped with a manual reset mechanism that must be manually reset before the burner can be restarted. This is usually accomplished with the use of a second or auxiliary control that has this feature.

Since low water cutoff devices are generally set by the original manufacturer, no attempt should be made to adjust these controls to alter the point of low water cutoff or point of pump cut-in or cut-out. If a low water device should become erratic in operation or if its setting changes from previous established levels, check for reasons and correct, repair or replace as required.

These controls normally function for long periods of time which may lead to laxity in testing on the assumption that normal operation will continue indefinitely.

The controls' operation may be checked by stopping the water supply to the boiler while the burner is operating at low fire. While under constant attendance allow the water to lower at a normal rate. If a control does not break the circuit to stop the burner at the proper point, then **SHUT DOWN THE BURNER IMMEDIATELY.**

Do not restart until all cross connecting piping is checked for obstructions. Also check the float bowl. If these are clean, repair or replace the control.

Repeat the above test to insure proper operation prior to returning the boiler to service.

On a steam boiler, the head mechanism of the low water cutoff device(s) should be removed from the bowl at least once a month to check and clean the float ball, the internal moving parts, and the bowl or water column.

Remove the pipe plugs from the tees or crosses and make certain the cross connecting piping is clean and free of obstructions. Controls must be mounted in a plumb position for proper performance. Determine that piping is vertically aligned after shipment and installation and throughout life of equipment.

A scheduled blowdown of the water controls on a steam boiler should be maintained.

It is impractical to blowdown the low water cutoff devices on a hot water boiler since the entire water content of the system would become involved. Many hot water systems are fully closed and any loss of water will require make-up and additional feedwater treatment that might not otherwise be necessary. Since the boiler and system arrangement usually makes it impractical to perform daily and monthly maintenance of the low water cutoff devices, it is essential to remove the operating mechanism from the bowl annually or

more frequently, if possible, to check and clean float ball, internal moving parts, and the bowl housing. Also check the cross connecting piping to make certain that it is clean and free of obstruction.

D. WATER GAUGE GLASS

A broken or discolored glass must be replaced at once. Periodic replacement should be a part of the maintenance program. Always use new gaskets when replacing a glass. Use a proper size rubber packing. Do not use “loose packing” which could be forced below the glass and possibly plug the valve opening.

Close the valves when replacing the glass. Slip a packing nut, a packing washer, and packing ring onto each end of the glass. Insert one end of the glass into the upper gauge valve body far enough to allow the lower end to be dropped into the lower body. Slide the packing nuts onto each valve and tighten.

If the glass is replaced while the boiler is in service, open the blowdown and slowly bring the glass to operating temperature by cracking the gauge valves slightly. After glass is warmed up, close the blowdown valve and open the gauge valves completely.

Check try-cocks and gauge cocks for freedom of operation and clean as required. It is imperative that the gauge cocks are mounted in exact alignment. If they are not, the glass will be strained and may fail prematurely.

A blowdown cock is provided on the lower gauge glass fitting and a daily blowdown is recommended.

E. OPERATING CONTROLS

In general, when adjusting controls check to see that they are level, especially those containing mercury switches. On temperature sensing controls make sure that the bulb is properly bottomed in its well. Make sure that connecting tubing is not kinked or damaged.

Controls are carefully calibrated during their manufacture and do not normally require re-calibration. The dial settings are generally quite accurate although it is not unusual to have a slight variation between a scale setting and an actual pressure gauge or thermometer reading and to re-adjust control setting to agree with these readings. This is predicated, however, on pressure gauges and thermometers being accurate.

Most of the operating controls require very little maintenance beyond occasional inspection. Examine tightness of electrical connections. Keep controls clean. If any dust accumulates in the interior of the control, remove with a low pressure air hose taking care not to damage the mechanism.

Examine any mercury tube switches for damage or cracks: this condition, indicated by a dark scum over the normally bright surface of the mercury, may lead to erratic switching action. Make certain that controls of this nature are correctly leveled using the leveling indicator if provided. Piping leading to various controls actuated by pressure should be cleaned if necessary. Covers should be left on controls at all times.

Dust and dirt can cause excessive wear and overheating of motor starter and relay contacts and maintenance of these is a requirement. Starter contacts are plated with silver and are not harmed by discoloration and slight pitting. Do not use files or abrasive materials such as sandpaper on the contact points since this only wastes the metallic silver with which the points are covered. Use a burnishing tool or a hard surface paper to clean and polish contacts. Replacement of the contacts is necessary only if the silver has worn thin.

Thermal relay units (overloads) are of the melting alloy type and when tripped, the alloy must be given time to resolidify before relay can be reset. If overloads trip out repeatedly when motor current is normal, replace them with new overloads. If this condition continues after replacement, it will be necessary to determine the cause of excessive current draw.

Power supply to the boiler must be protected with dual element fuses (fusetrans) or circuit breakers. Similar fuses should be used in branch circuits and standard one-shot fuses are not recommended.

1. Setting and Adjusting

Burner controls properly set to match load demands will provide operational advantages and achieve the following desirable objectives:

1. The burner will be operating in low fire position prior to shut down.
2. The burner will operate at low fire for a brief period on each start during normal operation.
3. Eliminates frequent burner on-off cycling.

Normal operation of the burner should be with the damper positioning switch in the "auto" position rather than either "low" or "high". This allows the burner to automatically shift from one firing rate to the other in accordance with load requirements.

When firing a cold boiler, it is recommended that the burner be kept under manual flame control until normal operating pressure or temperature is approached. If the burner is not under manual control on a cold start, it will immediately move to high fire.

The Model 5 boiler is designed to withstand considerable change in steam pressure or water temperature, however, good operating practice with any boiler is to avoid rapid and frequent variations. Therefore, it is advantageous to set the controls so that the burner is in low-fire position before shutdown and so that it does not immediately go to high fire upon a restart.

Any control setting must not cause the boiler to operate at or in excess of the safety valve setting. Settings that do not exceed 90% of the valve setting are recommended, with lower settings greatly desirable if load conditions permit. Avoid having the operating pressure too near the valve set pressure, because the closer the operating pressure is to the valve pressure, the greater the possibility of valve leakage. Continued leakage, however slight, will cause erosion and necessitate early valve replacement. The control settings on a hot water boiler must be within the temperature and pressure limits of the boiler.

Ideally, the burner operating controls should be set under actual load conditions. Often, especially on new construction, the boiler is initially started and set to operate under less than full load requirements. As soon as possible thereafter the controls should be reset to provide maximum utilization of the firing system.

In the setting of these controls, consideration must be given to the time required for a burner restart. Upon each start, there is a pre-purge period of some length, plus the fixed time required for the proving of the pilot and main flame. This, plus the time required for damper motor travel from low to high fire, may allow pressure or temperature to drop below desirable limits.

The mechanics of setting the controls are:

2. Pressure Controls — Steam Boiler

The pressure controls that serve as the operating limit control and as the high-low fire control are equipped with an adjustable differential setting. See the following portion of this section for adjustment procedures.

The switch in the control opens when the steam pressure reaches a pressure equal to the main scale setting and closes at a pressure equal to that shown on the main scale, MINUS the amount of differential.

In an installation that does not require very close control of the steam pressure, the differential setting should be adjusted to its maximum, since this will provide less frequent burner cycling.

The high-low fire control should be set to open at 5 to 10 psi lower than the operating limit setting. The suggested setting on a low pressure steam boiler is 2 to 3 psi. The differential setting on this control may be set low, to give quite close

control of steam pressure. In any case, the control should be adjusted so that it opens and causes the burner to go to low fire at a pressure below the limit control opening point. When the pressure controls are properly set, the burner will maintain steam pressure within narrow limits.

On a rise in steam pressure, the high-low fire control opens its contacts and the damper motor returns to low-fire position. The burner continues to operate at low fire rate. If steam pressure drops, the control will again close to complete the circuit and return the burner to high fire. If steam pressure continues to rise, the boiler will remain at low fire rate. Should the boiler pressure reach the set point of the operating limit control, its contacts will open to turn off the burner. When boiler pressure drops, the operating limit control contacts close, causing the burner to restart. It is desirable to have the high-low fire control adjusted so that the burner does not immediately go to high fire upon start, but rather operates at low for a brief period before decreasing steam pressure causes control to close and the burner to drive to high fire.

Operating Limit Pressure Control (Steam) (Honeywell L404A)

Set “cut-out” (burner off) pressure on the main scale using the large adjusting screw. Set differential on the short scale turning the small adjusting screw until the indicator points to the desired difference between cut-out and cut-in pressures. The “cut-in” (burner on) pressure is the cut-out pressure MINUS the differential. The cut-out pressure should not exceed 90% of the safety valve setting.

High Limit Pressure Control (Steam) (Honeywell L404C)

Set “cut-out” (burner off) pressure oil scale using adjusting screw. The control will break a circuit to shut off burner when pressure reaches this point. The setting should be sufficiently above the operating limit pressure control to avoid shutdowns, and preferably not exceed 90% of safety valve setting. This control requires manual resetting after tripping on a pressure increase. To reset, allow boiler pressure to return to normal and then press the reset button.

High-Low Fire Control (Honeywell L404A) (Steam)

Set the “cut-out” pressure — the point at which the burner will return to low fire — on the main scale using the large adjusting screw. This setting should be sufficiently below the cut-out setting of the operating limit control so that the burner will return to the low fire position prior to shutting off at the operating limit.

The “cut-in” pressure — the point at which the burner drives to high fire — is set on the differential scale. This setting is equal to the cut-out pressure MINUS the amount of the differential. It should be adjusted so that it is sufficiently

below the burner “on” pressure of the operating control so that the burner when starting will operate briefly at the low fire position prior to advancing to high fire.

3. Temperature Controls — Hot Water Boiler

The temperature controls that serve as the operating limit control and as the high-low fire control are equipped with an adjustable differential setting. The switch in the control opens when the water temperature reaches a temperature equal to the dial setting and closes at a temperature equal to the dial setting MINUS the amount of differential. See following portion of this section for instructions on control adjustment.

In an installation that does not require very close control of the water temperature, the differential setting should be adjusted as widely as possible since this will provide less frequent burner cycling.

The operating limit temperature control should be set slightly above the highest desired water temperature and within the limits of the pressure vessel. The high limit control should be set 5 to 10 degrees above the operating limit temperature control setting. The high-low fire control should be adjusted so that it is below the burner “on” temperature of the operating control.

Relative settings of the temperature controls are as follows:

- High Limit Control
Open – 200°F
- Operating Limit Control
Open – 190°F
Close – 180°F
- High-Low Fire Control
Open – 180°F (Low Fire)
Close – 175°F (High Fire)

With settings similar to these, the following operational sequence occurs. On a rise in boiler water temperature, the high-low fire control opens its contacts at 170 degrees F to de-energize the damper motor and place the burner in its low fire range.

If temperature decreases during low fire, the burner will return to high fire as soon as the high-low fire control closes at its 175 degree setting. As temperature increases during high fire rate, the burner will be switched back to low fire when the control opens at 180 degrees.

If temperature increases during low fire, the burner will shut down when the operating limit setting of 190 degrees is reached. When temperature drops back to 180 degrees the operating limit will close to restart the burner. The unit will fire at its low rate unless temperature continues to drop to

175 degrees, at which time the high-low fire control will close to move the burning rate to high fire.

The settings listed are typical and will vary according to job requirements. However, setting the controls with these relations to each other is desirable, since this will prevent the burner from shutting down while in high fire or from immediately going to high fire upon restarting.

Operating Limit Temperature Control (Hot Water) (Honeywell L4008A)

Set “cut-out” (burner off) temperature on scale by inserting a screwdriver through the cover opening to engage the slotted head adjusting screw.

The “cut-in” (burner on) temperature is the cut-out temperature MINUS the differential. The differential is adjustable from 5 to 30 degrees F. Differential is adjusted by rotating the wheel on the back of the snap switch.

High Limit Temperature Control (Hot Water) (Honeywell L4008E)

Set the “cut-out” (burner off) temperature on scale using adjusting screw. This control will break the circuit and lockout on a rise in water temperature above the setting. The setting should be sufficiently above the operating limit temperature to avoid unnecessary shutdowns. On 30 lb. hot water generators the setting is not to exceed 240 degrees F. The control requires manual resetting after tripping on a temperature increase. To reset allow water temperature to drop below the cut-out setting, less differential, and then press the manual reset button.

High-Low Fire Control (Hot Water) (Honeywell L4008A)

Set the “cut-out” temperature — the point at which the burner will return to low fire — on the indicating dial. This setting should be sufficiently below the cut-out setting of the operating limit temperature control so that the burner will return to the low-fire position prior to shutting off at the operating limit.

The “cut-in” temperature — the point at which the burner drives to high fire — is set on the differential scale. This setting is equal to the cut-out temperature MINUS the amount of the differential. It should be adjusted so that it is sufficiently below the burner “on” temperature of the operating control so that the burner when starting can operate briefly in the low-fire position prior to advancing to high fire.

4. Combustion Air Proving Switch

Air pressure against the diaphragm actuates the switch which, when made, completes a circuit to prove the presence of the combustion air. Since the pressure of the combustion

air is at its minimum value when the damper is full open, the switch should be adjusted under that situation. It should be set to actuate under a condition of minimum pressure, but not too close to that point to cause nuisance shutdowns.

5. Low Gas Pressure Switch

Turn adjusting screw until indicator on scale moves to a pressure setting slightly below the operating gas pressure. The control will break a circuit if pressure is below this value. The control should be finally adjusted to prevent operation with low gas pressure, but should not be set at a value close enough to normal operating pressure to cause unnecessary shutdowns. When setting this control consideration must be given to the fact that gas line distribution pressure may decrease under some conditions and it is advisable that the control does not cut out unnecessarily.

The switch must be manually reset after tripping on a drop of gas pressure below the cut-out setting. To reset allow gas pressure to rise and press the manual reset button.

6. High Gas Pressure Switch

Turn adjusting screw until indicator on scale moves to a pressure setting slightly above the maximum operating gas pressure. The control will break a circuit if pressure exceeds this value. The control should be adjusted to prevent operation with excessive gas pressure but should not be set at a value close enough to normal operating pressure to cause unnecessary shutdowns.

This switch must be manually reset after tripping on a rise of gas pressure above the cut-out setting. To reset allow gas pressure to drop and press the manual reset button.

7. Low Oil Pressure Switch (Optional)

This control prevents burner from igniting or stops its operation when the oil pressure is below a preset point. The control contains a single-pole, single-throw mercury switch which closes on a pressure rise. Pressure settings are made with the knobs on the face of the control. The “low” setting indicates the point at which switch action takes place on a pressure drop. Initially set this knob to the bottom of the scale. Adjust the “high” knob to a point slightly below the normal operating oil pressure. Then set “low” knob somewhat lower, but not less than 150 psi. The burner will operate as long as oil pressure exceeds the lower setting.

8. Programming Control

This control requires no adjustment, nor should any attempt be made to alter contact settings. The contacts may require occasional cleaning. If so, follow instructions given in the manufacturer's bulletin. Do not use abrasive materials. The control cabinet door should be closed during normal operation.

The manufacturer's bulletin also contains troubleshooting information.

The flame detector lens should be cleaned as often as operating conditions demand. Use a soft cloth, moistened with detergent if necessary. The UV sensing tube within the flame detector is not field replaceable. If the flame detector is replaced be sure to properly connect the blue lead to the F terminal and the white lead to the G terminal. Reversing the leads even momentarily may destroy the UV tube.

Replacement of internal components, other than the plug-in amplifier is neither practical nor recommended.

 Caution

When replacing a control or cleaning contacts, be sure to open the main power supply switch, since the control is "hot" even though the burner switch is off.

A periodic safety check procedure should be established to test the complete safeguard system at least once a month or oftener. Tests should verify safety shutdown and a safety lockout upon failure to ignite the pilot, upon failure to ignite the main flame, and upon loss of flame. Each of these conditions should be checked on a scheduled basis. These tests will also verify fuel valve tightness.

Checking Pilot Flame Failure

Close the gas pilot shutoff cock. Also shut off the main fuel supply. Turn the burner switch "on". The pilot system will be energized at the end of the pre-purge period. Since there is no pilot flame to be detected, the pilot valve will be de-energized and the main fuel valves will not be energized. Check to see that there is an ignition spark but no flame. The programmer will complete its cycle during which time the lockout switch will trip on a safety lockout.

Turn the burner switch off. Reset the safety switch after allowing the thermal element to cool for a few moments. Reopen the gas pilot shutoff cock and reestablish main fuel supply.

Checking Failure to Light Main Flame

Leave the gas pilot shut off cock open. Shut off the main burner fuel supply. Turn the burner switch on. The pilot will light upon completion of the pre-purge period. The main fuel valve(s) will be energized but there should be no flame. Relay 2K should drop out within 4 seconds after main burner ignition trial ends. The safety switch should trip and lock out about 30 seconds after end of the ignition trial.

Turn the burner switch off. Reset the safety switch after allowing the thermal element to cool for a few moments. Re-establish the main fuel supply.

Checking Loss of Flame

With the burner in normal operation, shut off the main burner fuel supply to extinguish main flame. Relay 2K should drop out within 4 seconds after flame is extinguished. The blower motor runs during the post purge. The lockout switch will trip approximately 30 seconds later de-energizing master relay 1K.

Turn the burner switch off. Reset the safety switch after allowing the thermal element to cool for a few moments. Re-establish main fuel supply.

9. Control Operational Test

Proper operation of the various controls should be verified and tested when the boiler is initially placed into service or whenever a control is replaced. Periodic checks should be made thereafter in accordance with a planned maintenance program.

The operating limit control may be checked by allowing steam pressure or water temperature to increase until the burner shuts down. Depending upon the load, it may be necessary to manually increase the firing rate to raise steam pressure to the burner shutoff point. If load is heavy, the header valve can be closed or throttled until the pressure increases. Observe the steam gauge to check the cutoff pressure as the operating limit control shuts the burner down. Open the header valve to release steam pressure or vent steam and check the cut-in setting as the burner restarts. Check the high-low fire control for desired operating pressure range.

Water temperature, on a hot water boiler that may be operating at less than full load, may be raised by manually increasing the firing rate until the burner shuts down thru the action of the operating limit control. Observe the thermometer to verify the desired setting at the point of cutout and again when burner restarts. Check the high-low fire control for the desired operating temperature range.

Observe the ignition and programming control operations to make sure that they are correct. Check the proper operation and setting of the low water cutoff (and pump operating control, if used).

Proper operation of the flame failure device should be checked at time of starting and at least once a week thereafter. Refer to previous section for information on flame safety checks.

Check for tight shutoff of all fuel valves. Despite precautions and strainers, foreign material may lodge under a valve seat preventing tight closure. Promptly correct any conditions causing leakage.

F. OIL BURNER

1. General

There are relatively few adjustments that can be made to the burner drawer, however, a check should be made to see that all components are properly located and that all holding devices such as setscrews properly tightened. **Figures 6-1** and **6-2** cover typical burner drawers and show pertinent dimensions.

The burner drawer should be periodically inspected for evidence of damage due to improperly adjusted combustion. The air cooling tubes surrounding the nozzles should be inspected occasionally for any carbon residue or any clogging that might be caused by unusual dusty or lint-laden atmosphere. The setting of the oil nozzle in relation to the opening in the cooling tube is important and should be maintained.

Diffuser

Proper positioning of the diffuser should be maintained so that oil spray or flame does not impinge on it. Remove any carbon or other deposits if any have accumulated so that air flow pattern is not affected. Do not attempt to change the gap or angle of the fins.

Burner Nozzles

Efficient oil burner operation requires clean nozzles. The nozzles deliver a spray of extreme fineness to assure proper mixing with the air stream. If at any time the flame becomes “stringy or lazy” it is possible that one or more of the nozzles is clogged or worn. Even though the oil pressure gauge may indicate correct pressure, plugged or partially plugged nozzles will greatly reduce oil delivery.

The nozzles may be cleaned. However, if they appear worn or if they have been in service for a considerable time, it is more economical to replace them. Any cleaning should be done with a wood splinter rather than with any metal to avoid damaging the hole in the tip or the oil grooves. Check strainer and clean if necessary.

Nozzles may be of different capacities and it is extremely important that they are replaced in proper firing order. Nozzles can be identified by the capacity and spray angle stamped on them.

The capacity stamped on side of nozzle represents delivery rate with oil pressure at 100 psi. Since the burner is designed to use considerably higher atomizing oil pressures, the capacity of the nozzle is greatly increased. Do not assume that undersized nozzles are installed on the basis of nozzle marking compared to the burner input.

The oil pressure required for full burner input ranges from approximately 180 to 267 psi depending on boiler size. Oil

pressure is adjusted by the regulator in the fuel oil pump. If smoke occurs at open damper, the pressure should be adjusted downward to clear the fire. See the later section covering oil burner combustion adjustment.

Ignition System

Maintain the proper gap and dimensions of the ignition electrode(s) for best ignition results. **Figure 6-1** or **6-2** shows the correct settings.

Inspect electrode tips for signs of pitting or combustion deposits and dress as required with a fine file. Inspect the insulators of the electrodes and the feed through insulators for evidences of cracks or chipping. If any are present replace the items, since this can cause grounding of ignition voltage. Carbon is an electrical conductor, so it is necessary to keep the insulating portion of electrode wiped clean if any is present. Ammonia will aid in removing carbon or soot.

Check ignition cables for cracks in the insulation. Also see that all connections between transformer and electrodes are tight.

2. Oil Pump

The oil pump has a built-in strainer of the self-cleaning knife type that normally requires no servicing, however, any other strainers or filters in the suction line must be cleaned periodically.

Problems attributed to the pump can generally be traced to other causes such as broken or restricted fuel lines, lack of fuel, clogged filters, stuck or closed valves, a high vacuum or even an excessive head of oil. Improperly sized suction and return lines will cause problems.

The pressure gauge (**Figure 1-2**) reveals that the pump gears are pumping and building up a steady even pressure to deliver oil to the nozzles and at the pressure to which the integral regulator has been set. Collapse of the nozzle spray below the set limit can indicate worn internal parts, although these units are designed to give long periods of operation without undue wear. If this situation is verified, it is generally advisable to replace the pump. It is recommended that the removed pump be returned to the factory for complete reconditioning rather than field replacement of individual parts.

If the oil supply is below the level of the pump, a vacuum gauge can be installed at the suction port of the pump as this is helpful in checking the condition of the suction line and aids in pinpointing problems. Normally a vacuum reading should not exceed 10". Vacuums higher than this can lead to problems in oil separation or in erratic or declining delivery. Excessive readings can indicate restrictions such as kinked or clogged lines, sticking or closed valves, or even a frozen oil line. If there is no reading, look for air leaks in the

lines, valve fittings, or pump. On gravity fed installations a vacuum gauge should read zero. If not, this is evidence of restrictions being present.

If the oil supply is above the level of the pump, a pressure gauge can be installed in the pump bypass port for use in determining that the head of oil is not too great. If the head pressure is over 3 psi, damage or seal leakage can occur. A pressure reducing valve should be installed in this instance.

Seal leakage may also be caused by restrictions in the return line.

In an initial start-up a pump noise in the form of a whine may be noticed. This is a condition that results from air in the oil line and should cease as soon as the pump is able to clear the line of air. If the condition persists after a long period of operation, it may indicate a leak in the suction line.

Oil Pump Belt

The V-belt driving the oil pump requires no servicing and no preservatives or dressing compounds should be used. Belts normally stretch with use and proper tension should be maintained. Do not apply excessive tension since this can result in damage to the pump shaft bearings.

On a 200 series boiler, it is recommended that the belt be removed when gas is used for an extended period as this will prolong the life of the pump and belt.

3. Combustion Adjustment — Oil

Each boiler is adjusted prior to shipment from the factory, however circumstances caused by shipment, installation, or operating load conditions may require further adjustment to assure maximum operating efficiency and economy. Periodic rechecks of adjustments and settings are also recommended.

The burner system should be adjusted on the basis of a combustion efficiency analysis after the unit has been in operation sufficiently long to assure a warm boiler.

Proper air-fuel ratio should be established by the use of a combustion gas analyzer. This instrument measures the content by percent of carbon dioxide (CO₂), oxygen (O₂) and carbon monoxide (CO) in the flue gas. Efficiency is measured by the percentage of CO₂ present in the flue gas. The ideal setting from a standpoint of efficiency is reached when there is no measurable percentage of oxygen present. It is, however, more practical to set the burner to operate with a reasonable amount of excess air to compensate for minor variations in the pressure or burning properties of oil. 15 to 20 percent excess air is considered normal. A CO₂ range of 12 to 13% is desirable. The burner should never be operated with an air-fuel ratio that indicates a detectable percentage of carbon monoxide.

Turn the burner to high fire and let it operate at this rate for several minutes. Observe the color and size of the flame. Color alone is a poor means of determining efficiency, although it can serve as a guide for tentative setting. If smoke or haze is visible additional combustion air is required. If the flame is overly bright, rumbles or emits sparks, the amount of combustion air will have to be reduced.

Take a sample of flue gas with an instrument known to be in good working order and determine CO₂ reading. Based on this analysis, make any required adjustments to increase or decrease the air and/or oil flow.

Recheck low fire to determine whether it was affected by high fire adjustments. If so, additional linkage adjustment may be required.

G. GAS BURNER

1. General

There are relatively few adjustments that can be made to the burner drawer, however, a check should be made to see that all components are properly located and that all holding devices such as setscrews are properly tightened. Periodically inspect the burner drawer for evidence of damage due to improperly adjusted combustion.

Check the gas pilot electrode for proper setting (see **Figure 6-2**) and also for any cracks in the porcelain insulator. Cracks can cause grounding of ignition voltage. Check the tip of electrode for signs of pitting and dress as required. Check the ignition cable for insulation cracks. See that all connections between transformer and electrode are tight.

2. Gas Pilot Flame Adjustment

The size of the gas pilot flame is regulated by adjusting the gas flow through the pilot gas regulator. The flame must be sufficient to ignite the main flame and to be seen by the flame detector but an extremely large flame is not required. An overly rich flame can cause sooting of the flame detector. Too small a flame can cause ignition problems.

To check the pilot flame, visually observe it thru the rear sight port. A flame that encircles approximately one-half of the diffuser is satisfactory. To control the flame size, make the necessary adjustment to the gas pilot regulator.

A preferred method of setting a flame is to obtain a micro-amp reading of the flame signal. This can be measured with a good quality micro-ammeter or a suitable multi-meter with a zero to 25 micro amp DC rating.

The meter is connected to a jack in the amplifier of the flame safeguard control. Use a meter connecting plug harness (Cleaver-Brooks 884-72). Connect the plus (red meter lead)

to the red tab of the harness and the minus (black meter lead) to the black tab before inserting the plug in the meter jack.

1. To measure and adjust the pilot, turn the damper switch to low. Fully open the pilot shut-off cock. Close the cock in the main gas line.
2. Connect the micro-ammeter as outlined above.
3. Turn burner switch on. Let the burner go through the normal pre-purge cycle. When the ignition area of the timer dial is opposite the index notch, set the timer switch to the TEST position to stop the timer. Relay 2K should pull in when the pilot ignites.
4. If the pilot flame is not established within ten seconds, turn off the burner switch. Repeat the lighting attempt.

Note: On an initial starting attempt, portions of the fuel lines may be empty and require “bleeding” time. It is better to accomplish this with repeated short lighting trial periods with intervening purge periods than to risk prolonged fuel introduction. If the pilot does not light after several attempts, check all components of the pilot system.

5. When the pilot flame is established, remove the flame detector from the burner plate. The pilot flame can then be observed thru this opening
6. To make the final adjustment, slowly close the gas pilot regulator until the flame can no longer be seen through the sight tube. Then slowly open the regulator until a flame providing full sight tube coverage is observed.

This adjustment must be accomplished within the time limit of the safety switch or approximately 30 seconds after the detector is removed. If the control shuts down, allow several moments for the thermal element in the safety switch to cool and then manually reset it. Replace the detector and repeat from step 3.

7. When a suitable flame is obtained, replace the detector. Observe the reading on the micro-ammeter. The reading should be between two and five micro-amps and the reading must be steady. If the reading fluctuates, recheck the adjustment. Make sure that the flame detector is properly seated and that the lens is clean.
8. Reset the timer switch from the TEST position to the NORM position.
9. If main flame has not been previously established, proceed to do so in accordance with instructions elsewhere in the manual.
10. The micro-amp reading of the main flame signal should also be checked. Observe the flame signal for pilot alone, pilot and main burner flame together and the main burner

Caution

Keep eyes sufficiently away from the sight tube opening and wear a protective shield or suitable glasses. Never remove the flame detector while the main burner is firing.

flame at high, low, and intermediate firing rate positions. Readings should be steady and in the range indicated in step 7. If there are any deviations, refer to the troubleshooting section in the technical bulletin.

The gas burner housing surrounding the diffuser plate should be periodically checked for any signs of damage that might be caused by an improperly adjusted burner or by a poor seal to the refractory. Routine maintenance should include this resealing which can be done with a mixture of refractory cement and insulating pulp. Use care not to clog or obstruct the holes in the face of the gas housing.

The diffuser should be positioned as shown in **Figure 6-2**. Do not attempt to change the gap or angle of the fins.

3. Gas Pressure and Flow Information

Because of variables in both the properties of gas and the supply system, it will be necessary to regulate the pressure of the gas to a level that produces a steady, dependable flame that yields highest combustion efficiency at rated performance yet prevents overfiring. Once this optimum pressure has been established, it should be recorded and periodic checks made to verify that the regulator is holding the pressure at this level. Occasional modification in fuel composition or pressure by the supplier may, at times, require readjustment to return the burner to peak efficiency.

Pressure

The gas supplied must provide not only the quantity of gas demanded by the unit, but must also be at a pressure high enough to overcome the pressure loss due to the frictional resistance imposed by the burner system and the control valves.

The pressure required at the entrance to the burner train (downstream of the regulator) for rated boiler output is termed “net regulated pressure”. The gas pressure regulator must be adjusted to achieve this pressure to assure full input.

The pressure requirement varies with boiler size, altitude, and type of gas train. Refer to **Table 6-2** for pressure requirements.

The pressures listed are based on 1000 BTU/CU. FT. natural gas and elevations up to 700 feet above sea level. For installation at higher altitudes, multiply the selected pressure by the proper factor from **Table 6-1**.

Table 6-1 Altitude Correction Factors

Altitude Feet Above Sea Level	Correction Factor
1000	1.04
2000	1.13
2500	1.18
3000	1.22
4000	1.33
5000	1.44
6000	1.57
7000	1.70
8000	1.84
9000	2.01

Gas Flow

The volume of gas flow is measured in terms of cubic feet and is determined by a meter reading. The gas flow rate required for maximum boiler output depends on the heating value (BTU/CU. FT.) of the gas supplied. The supplying utility can provide this information.

To obtain the required number of cubic feet per hour of gas, divide the heating value (BTU/CU. FT.) into the required burner input from the burner data plate.

Pressure Correction

The flow rate outlined in the previous section is figured on a “base” pressure which is usually atmospheric or 14.7 psi.

Meters generally measure gas in cubic feet at “line” or supply pressure. The pressure at which each cubic foot is measured and the correction factor for this pressure must be known in order to convert the quantity indicated by the meter into the quantity which would be measured at “base” pressure.

To express the volume obtained from an actual meter reading into cubic feet at base pressure it is necessary to multiply the meter index reading by the proper pressure factor obtained from **Table 6-5**.

Conversely: to determine what the meter index reading should be in order to provide the volume of gas required for input, divide the desired flow rate by the proper pressure correction factor. This answer indicates the number of cubic feet at line pressure which must pass through the meter to deliver the equivalent number of cubic feet at base pressure.

As an example: assume that a size 3000 boiler is installed at 2,000 feet above sea level; is equipped with a standard gas train; and that 1,000 BTU natural gas is available with an incoming gas pressure of 3 psig. The pressure and flow requirements can be determined as follows:

Pressure — Correction for the 2,000 feet altitude must be made since altitude has a bearing on the net regulated gas pressure. The standard gas train requires 6.4" WC gas pressure at sea level (**Table 6-2**). **Table 6-3** indicates a correction factor of 1.13 for 2,000 feet. Multiplying these results in a calculated net regulated gas requirement of approximately 7.2" WC. This is the initial pressure to which the regulator should be adjusted. Slight additional adjustment can be made later, if necessary, to obtain the gas input needed for burner rating.

Flow — Since the gas flow rate is based on standard conditions of flow, correction must be made for the supply pressure through the meter of 3 psig. Determine the flow rate by dividing the BTU content of the gas into the burner input (**Table 6-4**) and "correct" this answer by applying the correction factor for 3 psig. (**Table 6-5**).

$$\frac{\text{BTU/HR}}{\text{Input}} = \frac{\text{CFH (Cubic Feet/ Hour)}}{\text{BTU/CU. FT.}}$$

OR

$$\frac{3,000,000}{1,000} = \frac{3000 \text{ CFH}}{\text{pressure}}$$

(At 14.7 lbs. atmospheric "base" pressure)

THEN

$$\frac{300}{1.18} = 2542 \text{ CFH}$$

This is the CFH (at line pressure) which must pass through the meter so that the equivalent full input requirement of 3000 CFH (at base pressure) will be delivered.

Regulator Inlet Pressure	Pressure Factor	Regulator Inlet Pressure	Pressure Factor
1 psig	1.05	9 psig	1.59
2 psig	1.11	10 psig	1.66
3 psig	1.18	11 psig	1.72
4 psig	1.25	12 psig	1.81
5 psig	1.32	13 psig	1.86
6 psig	1.39	14 psig	1.93
7 psig	1.45	15 psig	2.00
8 psig	1.52		

Checking Gas Flow

Your gas supplier can generally furnish a chart developed to determine the cubic feet/hour reading from the meter based on the number of seconds per revolution of the 10 cubic feet dial. This provides a knowledge of the flow rate after a relatively short observation period.

Lacking a chart of this nature it is possible to “clock the gas meter” as follows:

1. Turn off all other gas appliances that may be served by the meter.
2. Set burner at high fire.
3. Note meter reading and record consumption for 3 minutes.
4. The following formula will provide the required gas input for a 3 minute period:

$$\text{Input (BTU/HR)} \div \text{Heating Value (BTU/CU. FT.)} \div 20 = \text{Gas input in cubic feet for 3 minutes.}$$

5. Apply any necessary pressure correction factor to this answer to obtain the desired rate.
6. To illustrate, using circumstances from previous example, compute as follows:

$$\text{BTU/HR} \div \text{BTU/CU. FT.} \div 20 = 3 \text{ minute input in cu. ft.}$$

OR

$$3,000,000 \div 1000 \div 20 = 150 \text{ cu. ft. (base pressure)}$$

$$150 \div 1.18 \text{ (pressure correction)} = 127 \text{ cu. ft. (line pressure)}$$

7. If the input timed for 3 minutes does not agree with the rating indicated by the formula, adjust the gas pressure regulator to increase or decrease flow as required.

Note: The information given in this section is for all practical purposes sufficient to set and adjust controls for gas input. Your gas supplier can if necessary furnish exact correction factors that take into consideration BTU content, exact base pressure, specific gravity, temperature, etc., of the gas used.

4. Combustion Adjustment — Gas

Gas input adjustment is accomplished by increasing or decreasing the pressure of gas downstream of the pressure regulator. Any required adjustment to the regulator should be done with burner at high fire and with the gas butterfly valve wide open.

In the event linkage or regulator adjustments are required, proceed as follows. Initially set the linkage by backing out the low fire stop screw so the valve is closed. Then turn screw

in two complete turns. Adjust the connecting rod so that tension is released.

It is not practical to list specific setting of the connection points or of the angles of the arms. The final setting should provide a coordinated movement of the damper and the gas valve. If the gas valve opens rapidly compared to the air damper, an overly rich fire will occur during transition between the two firing positions. This improper fuel-air ratio can cause sooting of the fireside surfaces. If it opens too slowly then the proportionally greater air flow could extinguish the flame.

Points to remember are that the motor arm must complete its full travel and that the valve arm should travel its required arc without excessive stretching of the override springs. The closer that the swivel joint in the motor arm is to the hub, the less distance it will travel. To increase the valve arm travel, move the connecting rod closer to the hub or away from it if decreased travel is required.

This low fire setting should be regarded as tentative until proper gas pressure for high fire operation is established.

After operating at low fire for a sufficient period of time to assure a warm boiler, turn the damper positioning switch to "high". Observe the burner as it progresses toward high fire. In the event gas pressure is too low or if the butterfly valve movement is not properly coordinated with the air damper, it is possible that increased air flow may extinguish the flame. Immediately turn burner off. Determine and correct condition causing flame failure before repeating attempt.

At high-fire position, the butterfly valve should be wide open as indicated by the slot on the end of its shaft. Set and lock the high fire stop screw until it is just touching the valve arm.

Determine the actual gas flow from a meter reading as outlined in another section. If corrections are necessary to obtain the required input, increase or decrease the gas pressure by adjusting the pressure regulator. Turn its adjusting screw clockwise to increase pressure, or counterclockwise to decrease pressure.

When the high fire gas flow is established, no further adjustment of the regulator is required.

With proper gas flow, any further adjustment necessary to obtain a desirable flue gas analysis must be done with the air damper. Check all adjustments with a combustion gas analyzer.

When the high fire air fuel ratio is set, shut the burner down, relight and check low fire. It may be necessary to readjust the low fire stop screw or the linkage. To assure that low-fire position of the butterfly valve is always the same, allow a minimum of one turn of the stop screw for over-travel.

Any adjustment must not cause extensive stretching of the override springs. If linkage adjustments are made, recheck to determine that high fire is not affected.

The appearance or color of the gas flame is not an indication of its efficiency since an efficient gas flame will vary from transparent blue to translucent yellow.

Proper setting of the air/fuel ratios at all rates of firing must be established by the use of a combustion gas analyzer. This instrument measures the content, by percentage, of carbon dioxide (CO₂), oxygen (O₂), and carbon monoxide (CO) in the flue gas.

Burner efficiency is measured by the amount or percentage of CO₂ present in the flue gas. The theoretical maximum CO₂ percentage for natural gas is approximately 11.7%. This is attained when there is no excess oxygen (O₂) or carbon monoxide (CO). A definite percentage of excess air (oxygen) is required by most local gas authorities and, of course, the burner should never be operated with an air-fuel ratio that indicates a detectable percentage of carbon monoxide.

Subject to local regulations pertaining to specific amounts of excess oxygen, it is generally recommended that CO₂ readings of between 9-1/2 and 10-1/2% be attained with corresponding O₂ readings of 2 to 4%.

Water washing of the fireside surfaces of a gas fired boiler is usually not required. Washing lances are not provided although a gas burning boiler — Series 700 — does have provisions for their addition. If stack temperatures indicate a need for washing, lances can be ordered from your agent. However, a condition of this nature would indicate a definite maladjustment of the burner that requires attention and correction.

H. DAMPER MOTOR AND AUXILIARY SWITCHES

The damper motor, in addition to controlling the damper (and the gas valve linkage) contains one, or two, internal switches which serve as a Low Fire Switch and, if required, a High Fire Switch. These switches are actuated by cams attached to the shaft of the motor. They are factory set and should not normally require any adjustment.

If adjustment is required to the internal switches, loosen the locking screw on the cam assembly about one half turn. Do not remove the cam assembly.

With the motor in its fully closed position, rotate the cam counterclockwise until the switch makes an “audible click”. Adjust the cam so that the slow-rise portion of the lobe engages the switch lever to operate the switch. This gives a switching differential of approximately 10°.

The Low Fire Switch (LFS) used on all boilers must be closed to complete programmer circuitry that assures that the damper is in the low-fire position before ignition takes place. The switch opens when the damper motor drives to open during pre-purge and closes when it returns to low-fire position on completion of pre-purge. The switch, therefore, must be actuated just prior to the damper reaching its closed position.

The High Fire Switch (HFS), when required, is used to prove that the air damper opens during the pre-purge. Its terminals should make when the damper is nearly open and just before the timing of the programmer returns the motor to low-fire position.

Oil Valve Switches

Attached to the damper motor is an auxiliary control containing two switches. See **Figure 6-3**.

The first switch (left hand side) is used for the intermediate oil valve. The right hand switch is used for the high fire oil valve.

The following directions are based on adjusting the switch prior to its attachment to the damper. While particularly useful during replacement, they will also serve as a guide for final adjustment.

1. BEFORE attaching the switch to the mounting bracket, depress the scale lock and rotate the scale so that the zero mark of the outer scale on the silver scale is at the index mark.
2. Release the scale lock. Remove the thumb nut and the top set of cams.
3. Loosen both cam locking screws on the remaining set of cams. Align the two cam lobes so that only the operational cam (silver colored) will cause switch lever movement. Tighten the differential cam screw.
4. The switching action desired is for the normally open leads (red and blue) to close as the motor travels from low to high fire. Using the index mark as a reference point, push the scale lock down and turn the scale counterclockwise approximately 10° (motor stroke is 90°). Release the scale lock.
5. Turn cam until the cam roller of the switch lever is exactly over the outer corner of the operational cam lobe. A slight movement of the cam at this point should produce an audible click in the switch. Tighten the operational cam's locking screw.
6. No cam differential is desired between the make and the break of the contacts, so be sure that the differential cam lobe (brass colored) and the operational cam lobe are

aligned so that the differential cam has no effect on the switch.

7. Place the second set of cams on the shaft. Make sure that the operational cam's locking screw is on the opposite side of the shaft of the switch the cam is to operate (when the scale plate is set at zero).
8. Adjust the cam lobes as described in step 3.
9. Depress the scale lock. Turn the cam so that the cam roller of the No. 2 switch lever is exactly over the outer corner of the operational cam lobe when the scale indicates 60°. Replace and tighten thumb screw.
10. Connect the red and blue leads to the oil valve circuit as shown on the wiring diagram. The yellow lead is not required and its end should be insulated to prevent short circuits.
11. Check the operation of the switches under actual operating conditions. Make any necessary cam adjustments to insure that the oil valves open at the desired point.

The variables involved may require adjustment of the cams under operating conditions. The point of valve actuation is directly related to the amount of damper travel on a particular burner. The first switch should be actuated to close midway between low and high fire. This causes the intermediate oil valve to open and the second nozzle to fire, providing an increased firing rate for a smoother changeover between the low and high fire rates and vice versa. As the air damper moves towards the high-fire position, an increasing amount of air is allowed into the boiler. The valve should open in approximately mid range of the air input but definitely at a point where sufficient air is present so that there is no incomplete combustion or smoke. The positioning of the cam must be guided while observing the fire or stack when the valve opens. If smoke or haze is noticed, reposition cam to slightly retard valve opening.

The second oil valve switch should be actuated just as the damper reaches its open position. Based upon a combustion analysis, a damper position linkage adjustment may be required to provide more or less air at this point.

I. AIR DAMPER ADJUSTMENT

The arms and connecting rod that transmit motion from the damper motor to the air damper (and to the gas butterfly valve on a gas fired unit) are set at the factory and should not normally need further adjustment.

If adjustments are required, or to aid in determining the position of linkage in event of replacement, the following factors should serve as guides.

1. The damper motor should be able to complete its full travel range of 90 degrees. A restriction can cause damage.
2. Initial adjustment is done with the motor in its closed or unpowered condition. The power end of the shaft will be in its most counterclockwise position.
3. Secure the motor arm approximately 60 degrees below the horizontal centerline.
4. The slot on the end of the damper shaft indicates the position of the damper blade.
5. It is not practical to list specific setting of all of the connections or of the damper arm angle, since adjustment conditions must exist to meet combustion requirements or load conditions.
6. The closer the swivel joint in the motor arm is to the hub, the less distance it will travel.
7. The amount of damper opening increases when its connecting joint is closer to the hub. To decrease opening, move the ball joint away from the hub.
8. Final adjustments should result in a coordinated movement of the damper and damper motor.

Normally, at low fire the damper blade is cracked slightly open. With the burner firing at its low rate, hold the damper shaft securely with pliers and loosen the setscrew on its arm. Manually close damper until a slight haze appears and then open until it clears. Tighten setscrews and for reference purposes mark the position of the shaft slot to indicate approximate low fire damper setting.

Turn the damper positioning switch to “high” and observe the burner as it progresses to high fire, to be sure that air flow is coordinated with fuel flow.

Too much air can extinguish the flame and damper travel must be regulated accordingly. When high-fire position is reached again observe the flame appearance. If it is hazy then more air is required. Determine approximate setting by following the procedure outlined in the previous paragraph to obtain a haze-free fire. Again, make a reference mark showing the open position.

Note: As pointed out in the sections pertaining to combustion adjustment, color is a poor indication of flame efficiency and should be used only for tentative adjustment. Final adjustments should be made based upon stack analysis and with proper fuel input.

With the limits of low fire and high fire damper travel determined from reference marks, adjustment can now be made to the connecting rod connections.

Periodically check for proper adjustment. Check tightness of setscrews to prevent slippage. Occasionally oil swivel joints with a graphite or silicone type lubricant.

J. SAFETY VALVES

The safety valve is a very important safety device and deserves attention accordingly.

The purpose of the valve(s) is to prevent pressure buildup over the design pressure of the pressure vessel. The size, rating and number of valves on a boiler is determined by the ASME Boiler Code. The installation of a valve is of primary importance to its service life. A valve must be mounted in a vertical position so that discharge piping and Code required drains can be properly piped to prevent buildup of back pressure and accumulation of foreign material around the valve seat area. Apply only a moderate amount of pipe compound to male threads and avoid overtightening as this can distort the seats. Use only flat jawed wrenches on the flats provided. When installing a flange connected valve, use a new gasket and draw the mounting bolts down evenly. Do not install or remove side outlet valves by using a pipe or wrench in the outlet.

A drip pan elbow or a flexible connection between the valve and the escape pipe is recommended. The discharge piping must be properly arranged and supported so that its weight does not bear upon the valve.

Do not paint, oil, or otherwise cover any interior or working parts of the safety valve. A valve does not require any lubrication or protective coating to work properly.

Follow the recommendations of your boiler inspector regarding valve inspection and testing. The frequency of testing, either by the use of the lifting lever or by raising the steam pressure, should be based on the recommendation of your boiler inspector, and/or the valve manufacturer, and in accordance with Sections VI and VII of the ASME Boiler and Pressure Vessel Code.

Avoid excessive operation of the safety valve as even one opening can provide a means of leakage. Safety valves should be operated only often enough to assure that they are in good working order. When a pop test is required, raise the operating pressure to the set pressure of the safety valve, allowing it to open and reseat as it would in normal service.

Do not hand operate the valve with less than 75% of the stamped set pressure exerted on the underside of the disc. When hand operating, be sure and hold the valve in an open position long enough to purge accumulated foreign material from the seat area and then allow the valve to snap shut.

Frequent usage of the safety valve will cause the seat and disc to become wire drawn or steam cut. This will cause the valve to leak and necessitate downtime of the boiler for valve

repair or replacement. Repair of a valve must be done only by the manufacturer or his authorized representative.

Avoid having the operating pressure too near the safety valve set pressure. A 10% differential is recommended. An even greater differential is desirable and will assure better seat tightness and valve longevity.

Steam is expensive to generate and, for the sake of economy, wastage should be avoided whenever possible.

The above comments, although written primarily for a safety valve on a steam boiler, are largely applicable to a relief valve on a hot water boiler. It is imperative that the discharge piping be properly supported to avoid valve distortion and that this piping is directed to a safe point of discharge.

K. MOTORIZED GAS VALVE

Should the valve fail to operate, check its operation by applying test leads of the proper voltage to terminals 1 and 2 of the actuator. Make certain that the main shutoff cock is closed prior to testing. If the actuator fails to operate, it must be replaced. The actuator is not field repairable nor should it be disassembled.

To remove the actuator, loosen the two 5/32" allen setscrews that hold the actuator collar to the valve bonnet.

After replacement, cycle the valve with the fuel shutoff to determine that it opens and closes. If the valve has a visual indicator, observe the colored indicator: yellow — shut; red — open.

The auxiliary switch normally used as a valve closed indication switch is replaceable as a component.

L. SOLENOID VALVES: GAS PILOT/FUEL OIL/VENT VALVES

Foreign matter between the valve seat and seat disc can cause leakage. Valves are readily disassembled, however, care must be used during disassembly to be sure that internal parts are not damaged during the removal and that reassembly is in proper order.

A low hum or buzzing will normally be audible when coil is energized. If valve develops loud buzzing or a chattering noise check for proper voltage and clean plunger assembly and interior plunger tube thoroughly. Do not use any oil. Make sure that plunger tube and solenoid are tight when reassembled. Take care not to nick, dent or damage the plunger tube.

Coils may be replaced without removing the valve from the line. Be sure to turn off power to the valve. Check coil position and make sure that any insulating washers or retaining springs are reinstalled in proper order.

M.REFRACTORY

The Model 4 Boiler is shipped with completely installed refractory. This consists of the burner tile, access door and a bed covering the lower drum.

The refractory should be checked for evidence of shipping damage and repairs made prior to initial firing.

Periodic inspection will keep the operator informed of the condition of refractory. Normal maintenance requires little time and expense and prolongs operating life. Frequent washcoating of all surfaces is recommended. High temperature, air-dry type mortar diluted with water to the consistency of light cream is used for this purpose. Coating intervals will vary with service and are best determined by inspection.

Face all joints or cracks by applying mortar with a trowel or finger tip. Do this as soon as cracks are detected. It is normal for refractories exposed to hot gases to develop thin "hairline" cracks. This is caused by expansion and contraction. Cracks up to 1/8 inch across may be expected to close at high temperatures. If there are any that are relatively large (1/8 to 1/4 inch) clean them and fill with high temperature bonding mortar.

Refractory, under normal conditions, will last for considerable periods before replacement is necessary.

In the event of spalling of the furnace floor, remove affected area and replace with a mix made from regular Furnas-Crete (Kaiser).

The burner tile are precast special shapes, and replacements can be ordered from your Cleaver-Brooks representative. Installation is generally done by working from inside of

furnace and through the access door. Dry fit all the segments and chip to fit, if necessary. Reinstall, using proper refractory cement. Make sure that all joints are tight and coated with cement. Mix insulating cement with refractory mortar and work the mixture into the crevices formed by the back of the tile and the boiler tube panel. It is important that a good tight seal be attained between the burner housing and the brick. Make sure that the insulating material is in place and cement all joints and crevices. Periodically check the seal and repack as required.

N. FUEL CHANGEOVER MAINTENANCE

A boiler that is equipped to burn either oil or gas is often run for extended periods on either one of these fuels. To insure that the alternate fuel system is in working order, it is suggested that the burner be changed over for a short run on a periodic basis such as monthly. This preventive maintenance will permit checking of fuel valves and controls to determine their standby readiness. Circulation of oil through the system on a unit primarily firing gas is beneficial to the pump.

O. FORCED DRAFT FAN

Rotation of the fan is counterclockwise when viewed from front of burner. If motor is ever replaced be sure that rotation is proper when motor leads are reconnected. Remove the oil pump belt before testing for motor rotation. Occasionally check to see that fan is securely tightened on motor shaft. A retaining washer on the end of motor shaft holds the fan in the proper position and there should be no rubbing or contact with the air inlet. If the boiler is installed in a dusty location check the vanes for deposits of dust or dirt; buildup of such deposits can cause a decrease in air capacity or lead to an unbalanced fan condition.

P. FURNACE ACCESS AND FIRESIDE CLEANING

The entire windbox is attached to a davit and can be swung aside from the boiler. A bolted panel is provided for furnace inspection or access.

To swing front head:

1. Remove access casing panels and insulation on both sides of boiler.

Disconnect the fuel lines at unions or other piping connections

 Caution

Make certain that fuel supply — oil and/or gas — is properly shut off prior to disconnecting.

2. Disconnect the sight tube cooling line.
3. Disconnect pressure control lines on a steam boiler. Remove the remote bulbs from the water controls on a hot water boiler.
4. Unbolt the windbox from the burner flange.
5. Swing the windbox assembly on its davit

 Caution

Check for interference for field installed wiring or piping.

6. Remove bolting from access panel.

Reassemble in reverse order. Check the condition of the gasketing on the access panel and on the burner flange and replace if necessary. Restore the fuel supply and check the tightness of all reconnected piping.

Before firing, remove the burner drawer and reseal the burner housing. See **Section** of this chapter.

Refer to appropriate sections in **Chapter 2** for information on cleaning of fireside and waterside boiler surfaces. Lubrication

Electric Motors

Manufacturers of electric motors vary in their specifications for lubrication and care of motor bearings and their recommendations should be followed.

Ball bearing equipped motors are pre-lubricated. The length of time a bearing can run without having grease added or the bearing replaced, will depend upon many factors. The rating of the motor, type of motor enclosure, duty, atmospheric conditions, humidity, and ambient temperatures are but a few of the factors involved.

Complete renewal of grease can, on some motors, be accomplished by forcing out the old grease with the new. Thoroughly wipe those portions of the housing around the filler and drain plugs (above and below bearings). Remove the drain plug (bottom) and free the drain hole of any hardened grease which may have accumulated. With the motor not running, add new grease through the filler hole until clear grease starts to come out of the drain hole. Before replacing the drain plug run the motor for 10 to 20 minutes to expel any excess grease. The filler and drain plugs should be thoroughly cleaned before they are replaced.

The lubricant used should be clean and equal to one of the good commercial grades of grease locally available. Some lubricants that are distributed nationally are:

Gulf Oil	– Precision Grease No. 2
Humble Oil	– Andok B
Texaco	– Multifak No. 2
Phillips	– 1 B + RB No. 2
Fiske Bros.	– Ball Bearing Lubriplate
Standard / Mobile	– Mobilux No. 2

Control Linkage

Apply a non-gumming dripless high temperature lubricant, such as graphite or a silicone derivative to all pivot points and moving parts. Work lubricant in well and wipe excess. Repeat application at required intervals to maintain freedom of motion of parts.

Solenoid valves and motorized valves require no lubrication. Burner Housing Seal

The area between the end of the burner housing and the refractory facing of the oven must be properly sealed to avoid damage. The condition of this seal must be checked prior to placing the boiler into initial operation and periodically thereafter. Whenever the front head is swung aside, it will be necessary to reseal this area.

Resealing can be accomplished by using a half and half mixture of insulating pulp and refractory cement. Remove the burner drawer and clean away as much of the old seal as possible. Force the sealing mixture around the outer perimeter of the burner housing using care to make sure that the holes in the gas housing are not obstructed. The use of a mirror can be helpful in making a proper seal.

Notes:



Section 7

Troubleshooting

A. Burner Does Not Start	7-2
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F. Damper Motor Does Not Operate	7-6

This section assumes that the unit has been properly installed and adjusted and that it has been running for some time prior to the trouble listed in the heading of each section. It is further assumed that the operator has become thoroughly familiar with both burner and manual by this time. The points under each heading are set down briefly as possible causes, suggestions or clues to simplify locating the source of trouble. Methods of correcting the trouble, once it has been identified, may be found elsewhere in this manual.

If the burner will not start, or operate properly, refer to this troubleshooting section and to the programming relay bulletin for assistance in pinpointing problems that may not be readily apparent. Familiarity with the programmer and other controls in the system may be obtained by studying the contents of this manual and the bulletin. Knowledge of the system and its controls will make troubleshooting much easier. Costly downtime or delays can be prevented by systematic checks of the actual operation against the normal sequence to determine the stage at which performance deviates from normal. Following a routine may possibly eliminate overlooking an obvious condition, often one that is relatively simple to correct.

If an obvious condition is not apparent, check the continuity of the circuits with a voltmeter or test lamp. Each circuit can be checked and the fault isolated and corrected. Most circuitry checking can be done between appropriate terminals on the terminal boards in the control cabinet or the entrance box. Refer to the schematic Wiring Diagram for terminal identification.

A. BURNER DOES NOT START

1. Main disconnect switch open.
2. Blown fuses, tripped overload, loose electrical connections.
3. Combustion control safety switch requires resetting.
 - A. Refer to instructions supplied with program relay (combustion control).
 - B. Check for 120 V power input to the program relay (combustion control).
 - C. Check for power to the blower motor).
 - D. Check that appropriate relay contacts are closed (see programmer bulletin).
4. Limit circuit not completed
 - A. Pressure or temperature is above setting of operating control.
 - B. Water below required level
 - 1). Low water light, if provided, should indicate this condition.

- 2). Check manual reset button, if provided, on low water control.
- C. Fuel pressure must be within settings of low pressure and high pressure switches.
- 5. Motor defective
- 6. If burner starts, but shuts down after a few seconds, check the air proving switch circuit.

B. No Ignition

- 1. Lack of spark
 - A. Electrode grounded or porcelain cracked
 - B. Improper electrode setting
 - C. Loose terminal on ignition cable: cable shorted
 - D. Inoperative ignition transformer
 - E. Check appropriate program relay contacts.
- 2. Spark but no flame
 - A. Lack of fuel — no gas pressure, closed valve, empty tank, broken line, etc.
 - B. Inoperative pilot solenoid or low fire oil valve
 - C. Insufficient or no voltage to gas pilot solenoid valve.
- 3. Low fire switch open
 - A. Damper motor not closed, slipped cam, defective switch
 - B. Damper jammed or linkage binding
- 4. Check interlocks.
- 5. Timer switch in TEST position and timer stopped in “pre-purge”

C. Pilot Flame, But No Main Flame

1. Insufficient pilot flame
2. Gas fired unit:
 - A. Manual gas cock closed
 - B. Main gas valve inoperative
 - 1). Low or high gas pressure (reset switch if necessary)
3. Oil fired unit:
 - A. Oil supply cut-off by obstruction, closed valve, or loss of suction
 - B. Pump inoperative; belt broken or slipping
 - C. No fuel
 - D. Inoperative solenoid valve
 - E. Check oil nozzles and lines.
4. Inoperative programmer
 - A. If appropriate relay does not pull in when pilot flame lights, check flame detector, contacts, amplifier.
 - B. Flame detector defective, sight tube obstructed or detector lens dirty
 - C. Check for voltage to fuel valve when appropriate relay activates.

D. Burner Stays in Low Fire

1. Pressure or temperature above high-low fire control setting
2. Damper positioning switch in wrong position
3. Inoperative damper motor (See Section F)
4. Defective high-low fire control
5. Binding or loose linkage, cams, setscrews, etc.
6. Check appropriate relay contacts.

E. Shutdown Occurs During Firing

1. Loss or stoppage of fuel supply
2. Defective fuel valve; loose electrical connection
3. Flame detector weak or not operative
4. Lens dirty or sight tube obstructed
5. If the programmer lockout switch has not tripped, check the limit circuit controls, interlock, or blower motor.
 - A. The flame failure light is energized by ignition failure, main flame failure, inadequate flame signal, or open control in the non-recycling interlock circuit.
 - B. The light will not be energized by the opening of any control in the limit circuit.
6. If the lockout switch has tripped:
 - A. Check fuel lines and valves.
 - B. Check flame detector.
 - C. Visually check appropriate timer and relay contacts, refer to program control manual.
 - D. Check blower motor and all interlocks.
 - E. Lockout switch malfunctioning
 - 1). Stuck contacts
7. Improper air-fuel ratio (lean fire)
 - A. Slipping linkage
 - B. Damper stuck open
 - C. Fluctuating fuel supply
 - 1). Temporary obstruction in fuel line
 - 2). Temporary drop in gas pressure
8. Interlock device inoperative or not operative

F. Damper Motor Does Not Operate

1. Damper positioning switch in wrong position
2. Linkage loose or jammed
3. Motor does not drive to open or close during pre-purge or close on burner shutdown.
 - A. Check appropriate contacts.
4. Motor does not operate on demand.
 - A. Damper positioning switch in wrong position
 - B. High-low fire control improperly set or inoperative
 - C. Check appropriate contacts.
5. Motor inoperative
 - A. Loose electrical connection.



Section 8 Parts

DESCRIPTION	PART NO.
L. F. INPUT -- GAS (MBH)	3200
L. F. INPUT -- OIL (MBH)	3200
AIR BOX	
AIR BOX ASS'Y PART NO.	427-00253
MODULAR CAM LINKAGE ASS'Y	
ASS'Y NUMBER	EX-06372-4
MOD. MOTOR	
HONEYWELL MODEL	9174C-1025
PART NUMBER	894-01373
Bracket Ass'y, Cam Trim Mounting	
Inverted	008-02055
Linkage Cams	
Gas Linkage Cam P/N (inverted)	313-00015 (RH)
Oil Linkage Cam P/N (inverted)	313-00017 (RH)
Gas Linkage Cam P/N (upright)	
Gas Linkage Cam P/N (upright)	
Oil Linkage Cam P/N (upright)	
Arm Ass'y (Heavy Spring)	
Gas P/N	476-00090
Oil P/N	476-00082
FAN HOUSING	
Fan Housing Assy Part No.	040-469 or RD-873
For Standard Air Switch Mounting	

BLOWER MOTOR	
MOTOR H.P.	7.5
208-460/3/60/3450 (ODP) Part No.	CB# 894-1420 (575V)
IMPELLER	
BLOWER WHEEL SIZE	18x3.0
PART NUMBER	192-00376
INLET CONE	
INLET CONE P/N	097-00399
Burner Housing	090-604 or
Burner Housing Part No.	EX-6400-4
Gas Only Part No.	021-0592
Combination Part No.	021-0591
AIR MIXING BAFFLE	
AIR MIXING BAFFLE PART NO.	009-0454
DIFFUSER	
DIFFUSER PART NO.	275-0517
CHOKE CONE	Revised 097-0391
CHOKE CONE P/N	or RD-857
OIL SYSTEM	
H. F. INPUT -- (GPH)	57.1
L. F. INPUT -- (GPH)	22.9
DRIVE COUPLING	819-202 revised
WEBSTER PUMP MODEL	2V023C
PART NUMBER	901-522
OIL SSO VALVES (2)	940-1520
METERING VALVE (HAUCK)	S-3-13
PART NUMBER	940-1436
LOW FIRE VALVE POSITION (OIL)	#5
high fire valve position (oil)	#1.75
RETURN LINE SOL. VALVE (1)	940-1302
OIL PRESS. SWITCH - 2 STAGE	ASCO SB10DV W/TJ10A11
PART NUMBER	817-810
LOW FIRE HOLD LIMITING POT (150 ?)	
NOZZLE / RETURN FLOW	Hago RFL
NOZZLE BODY PART NO.	890-290
OIL NOZZLE (GPH X DEG)	80x60
NUMBER REQ.	1
NOZZLE TIP PART NO.	899-312
NOZZLE PRESSURE	300 psi

LOW FIRE RETURN PRESS.	60
HIGH FIRE RETURN PRESS.	170
GAS TRAIN	
SIZE	2 “
GAS VALVE	Honwywell
MODEL	V4055D
MAIN GAS REGULATOR	Maxitrol
MODEL	210E
BUTTERFLY VALVE	
ECLIPSE	2.5 FP
PART NUMBER	940-01230
GAS PILOT	
PART NUMBER	125-00001
PILOT PRESSURE	4.0”
Gas Spuds	
Radial Spuds P/N	042-00122
Quantity	14
LOW FIRE MANIFOLD PRESS.	3.0
HIGH FIRE MANIFOLD PRESS.	21.0
FURNACE PRESS.	11.5
MIN. FURNACE DIMENSIONS	M5-8000LV

NOTES



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