$30.00 U.S.

CLEAVER-BROOKS MODEL

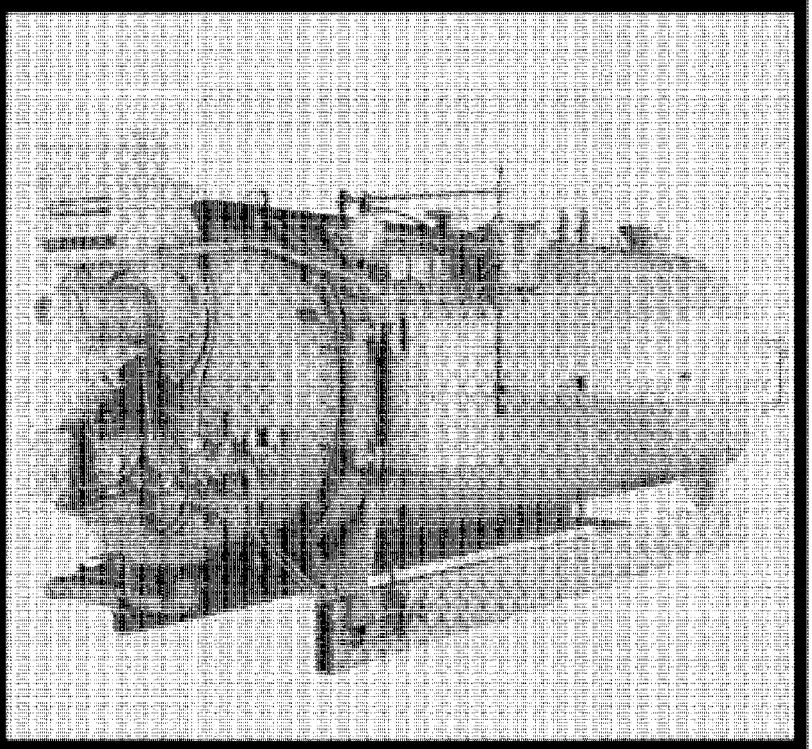
CBW

PACKAGED BOILERS

Operation, Service and Parts Manual

100 thru 400 HP

Fuel: Gas, Light Oil, Heavy Oil or Combination



Manual Part No. 750-150

Milwaukee, Wisconsin 53201

Service and Parts Coast to Coast
Boilers and Accessories for the Complete Boiler Room

CLEAVER-BROOKS
MODEL CBW
PACKAGED BOILERS

Operation, Service, and Part Manual

100 thru 400 HP

Fuel: Gas, Light Oil, Heavy Oil or Gas Combination

Cleaver-Brooks®

Please direct purchase orders for replacement manuals
to your local Cleaver-Brooks representative

Manual Part No. 750-150

Printed in U.S.A.

WARNING

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 warning 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 contractor's 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 know ability to perform; however, proper operating techniques and maintenance procedures must be followed at all times. Although these componesnts 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/her of certain repetitive chores and give him/her more time tot 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 boiler 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 tesing, assuming that normal operation will continue indefinitely. Malfunctions of controls lead to uneconomical operation and damage and, in most cases, these conditions ca nbe 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, nonthly 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 his/her 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 of extreme importance. 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 his/her operating personnel must comply with all requirements or regulations of his/her 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.

Safety Precautions and Abbreviations

1. Safety Precautions

It is essential to read and understand the following safety precautions before attempting to operate the equipment.

Failure to heed these precautions may result in damage to equipment, serious personal injury or death!

A complete understanding of this manual is required before attempting to startup, operate or maintain the equipment.

The equipment should be operated only by personnel who have a working knowledge and understanding of the equipment.

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

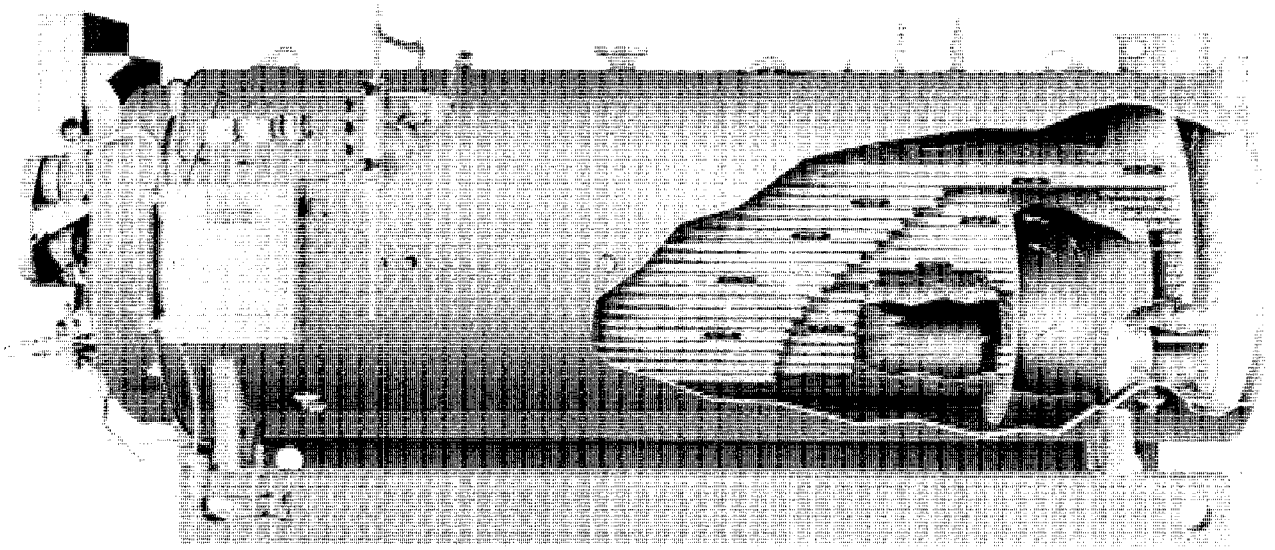
CAUTION!
This symbol indicates a potentially hazardous situation which, if not avoided, could result in damage to the equipment.

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

2. 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
ASTMD	American Society of Tables, Measures, Dimensions
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
FT	Feet
GPM	Gallons per Minute
Hd	Head
HT	Height
HTB	High Turndown Burner
HZ	Hertz
IRI	Industrial Risk Insurance
Lb	Pound
LWCO	Low Water Cutoff
MFD	Micro Farad
MR	Manual Reset
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 (Gauge)
SAE	Society of Automotive Engineers
T	Temperature
TC	Temperature Control
TI	Temperature Gauge
V	Volt
WC	Water Column
WSI	Watts Per Square Inch



THE THREE PASS CONSTRUCTION OF A TYPICAL CBW BOILER (CBW100 through 200 Boiler Horsepower Shown)

Combustion air enters through the air inlet. The forced draft fan forces air through the rotary air damper and diffuser into the combustion chamber. The main combustion chamber or main firetube constitutes pass one. A combustion turnaround section directs the gases into the second pass tubes. The turnaround section is contained within the pressure vessel, completely covered with water, giving the design name "WETBACK." Gases are directed from the second to the third pass at the front of the boiler and finally exit out the vent at the rear of the boiler.

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CHAPTER 1

GENERAL DESCRIPTION AND PRINCIPLES OF OPERATION

NOTE: If your boiler is equipped with a CB-HAWK™ boiler management control system, refer to CB-Hawk Installation, Operating, and Servicing Manual No. 750-133 for information regarding controls discussed in this section.

The general information in this manual applies directly to Cleaver-Brooks "CBW" Boiler Models in sizes ranging from 100 through 400 boiler horsepower for the following fuels:

Series 100 — Light Oil (No. 2)
Series 200 — Light Oil (No. 2) Or Gas
Series 400 — Heavy Oil (No. 6) Or Gas
Series 600 — Heavy Oil (No. 6) Only
Series 700 — Gas Only

NOTE: Although the Series 400 or 600 burner is designed and designated to burn No. 6 oil, the burner will handle grades 4 and 5 equally well with some possible modifications. While this manual contains pertinent information on

No. 6 fuel oil, all references to this fuel should be considered applicable to all grades of heavy oil.

The boiler and related equipment installation, by others, is to be in compliance with the standards of the National Board of Fire Underwriters. Installation also should 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 boilers in the above series comply, when equipped with optional equipment, to Industrial Risk Insurers (I.R.I.), Factory Mutual (FM), or other insuring underwriters requirements.

A. THE BOILER

The "CBW" Boiler is a packaged firetube boiler of welded steel construction and consists of a pressure vessel, burner, burner controls, forced draft fan, damper, air pump, refractory and appropriate boiler trim.

Rated Capacity	100 through 400 HP
Operating Pressure	Steam 15-250 psig, or higher if specified
Hot Water	30-250 psig or higher if specified
Fuel	Oil or Gas or Combination
Ignition	Automatic
Firing	Full Modulation Through Operating Ranges
Burner (Oil)	(Low Pressure) Air Atomizing
Burner (Gas)	Non-premix Orificed Type
Air Damper	Rotary Type (Electrically Modulated)
Steam Trim	ASME Code
Water Trim	ASME Code

The horsepower rating of the boiler is indicated by the numbers following the fuel series. Thus, CBW700-200 indicates a gas fired 200 HP boiler.

B. THE BURNER AND CONTROL SYSTEM

The oil burner is of the low pressure, air atomizing (nozzle) type. The gas burner is of the non-premix orifice type. The burners are ignited by spark ignited gas pilot. The pilot is of the interrupted type and is extinguished after the main flame is established.

NOTE: A Series 100 boiler is usually equipped with a light oil pilot although a gas pilot frequently is used.

The burners equipped to burn oil and gas include 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 a combination burner.

It is important that the burner model and serial number, shown on the nameplate, be included in any correspondence or parts order.

Regardless of which fuel is used, the burner operates with full modulation (within its rated operating range) through potentiometer-type positioning controls, and the burner returns to minimum firing position for ignition. High pressure boilers (above 15 psi) can be wired for both low pressure and high pressure modulation as optional equipment. This enables the boiler to operate at lower pressure during off-load hours, but at a somewhat reduced steam output dependent upon lower steam pressure and steam nozzle sizing.

The flame safeguard and program relay include a flame detector to supervise both oil and gas flames and to shut the burner down in the event of loss of flame signal. The programming portion of the control provides a pre-purging period, proving of the pilot and main flame, and a period of continued blower operation to postpurge the boiler of all unburned fuel vapors. Other safety controls shut down the burner under low water conditions, excess steam pressure or high water temperature.

The safety interlock controls include combustion and atomizing air proving switches and, depending upon the fuel and insurance carrier requirements, controls that prove the presence of adequate fuel pressure plus temperature proving controls when heated fuel oil is used.

The sequence of burner operation from start-up through shut-down is governed by the program relay in conjunction with the operating, limit and interlock devices, which are wired into the circuitry to provide safe operation and help to protect against incorrect operating techniques.

All "CBW" model boilers have the burner assembly attached to the front head. The entire head may be swung open for inspection and maintenance.

Combustion air is provided by a centrifugal blower located in the front head. Combustion air delivery to the burner is under the control of the damper motor. This same motor regulates the flow of gas fuel through a linkage system connected to the gas butterfly valve and the flow of fuel oil through a cam operated metering valve. Fuel input and air are thus properly proportioned for most efficient combustion.

Filtered primary air for atomizing fuel oil is furnished independently of combustion air by an air pump. The burner control circuit operates on 115 volt, single phase 60 hertz (or 50 hertz when so equipped) alternating current. The forced draft fan motor is generally operated on 3 phase service at the available main power supply voltage.

Indicator lights signaling load demand, fuel valve, low water, and flame failure conditions are standard equipment.

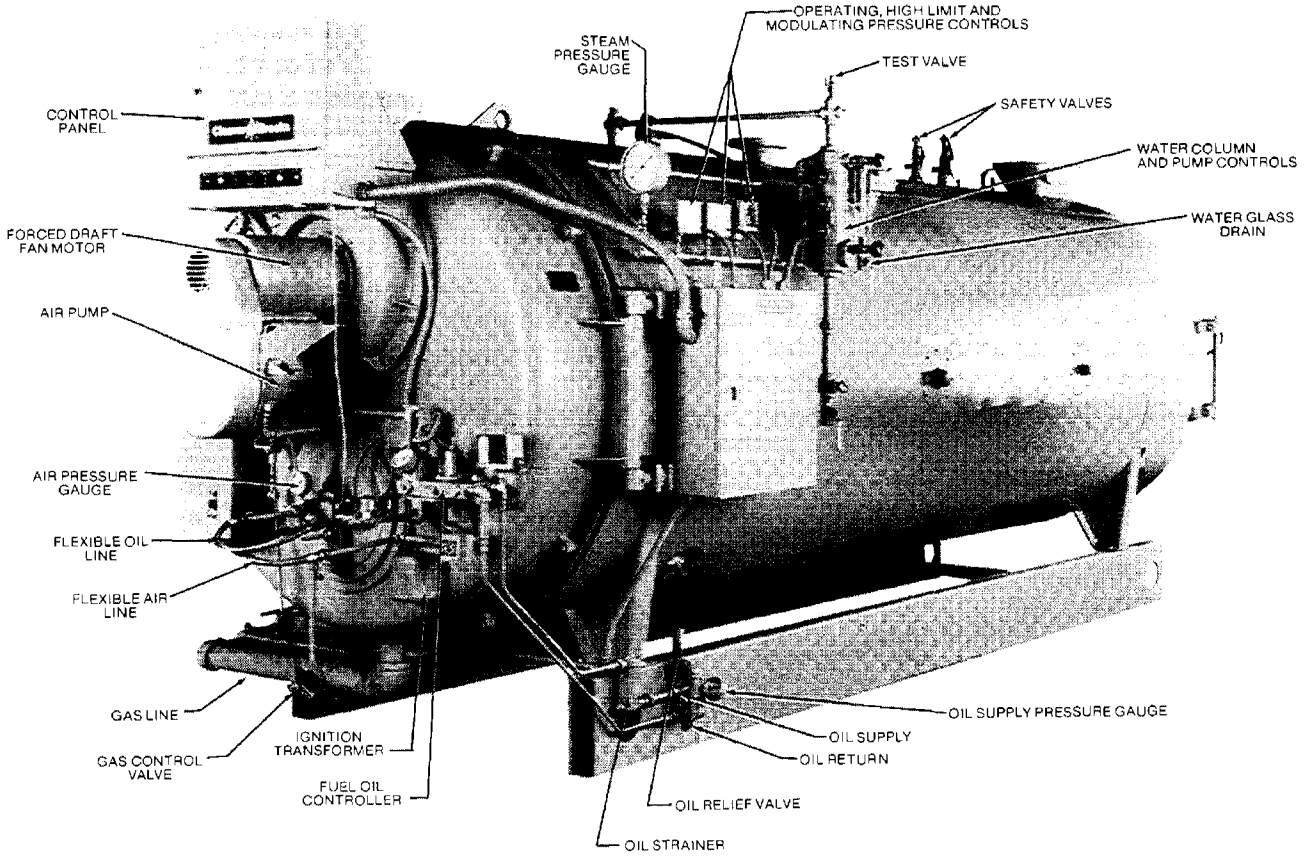
In addition to the standard basic controls supplied, other devices may be required to meet specific requirements of an insurance carrier or local code. Refer to the Wiring Wiagram (WD) prepared by Cleaver-Brooks for your specific installation to determine the specific controls in the burner and limit control circuits. The function of individual components is outlined in this chapter and the electrical sequence is covered in Chapter 3.

C. CONTROL AND COMPONENT FUNCTION

The term "control" covers the more important valves and components, including but not limited to electrical controls or those monitored by the program relay. The operator must become familiar with the individual functioning of all controls before he can understand the boiler's operation and procedures outlined in the manual.

Identify and locate each item using the figure callout.

The actual controls furnished with any given boiler will depend upon the type of fuel for which it is equipped and whether it is a hot water or steam boiler. Refer to the applicable group or groups listed which apply to the particular boiler.



[FIGURE 1-1 / TYPICAL STEAM BOILER — LIGHT OIL FIRED]

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

D. CONTROLS COMMON TO ALL BOILERS

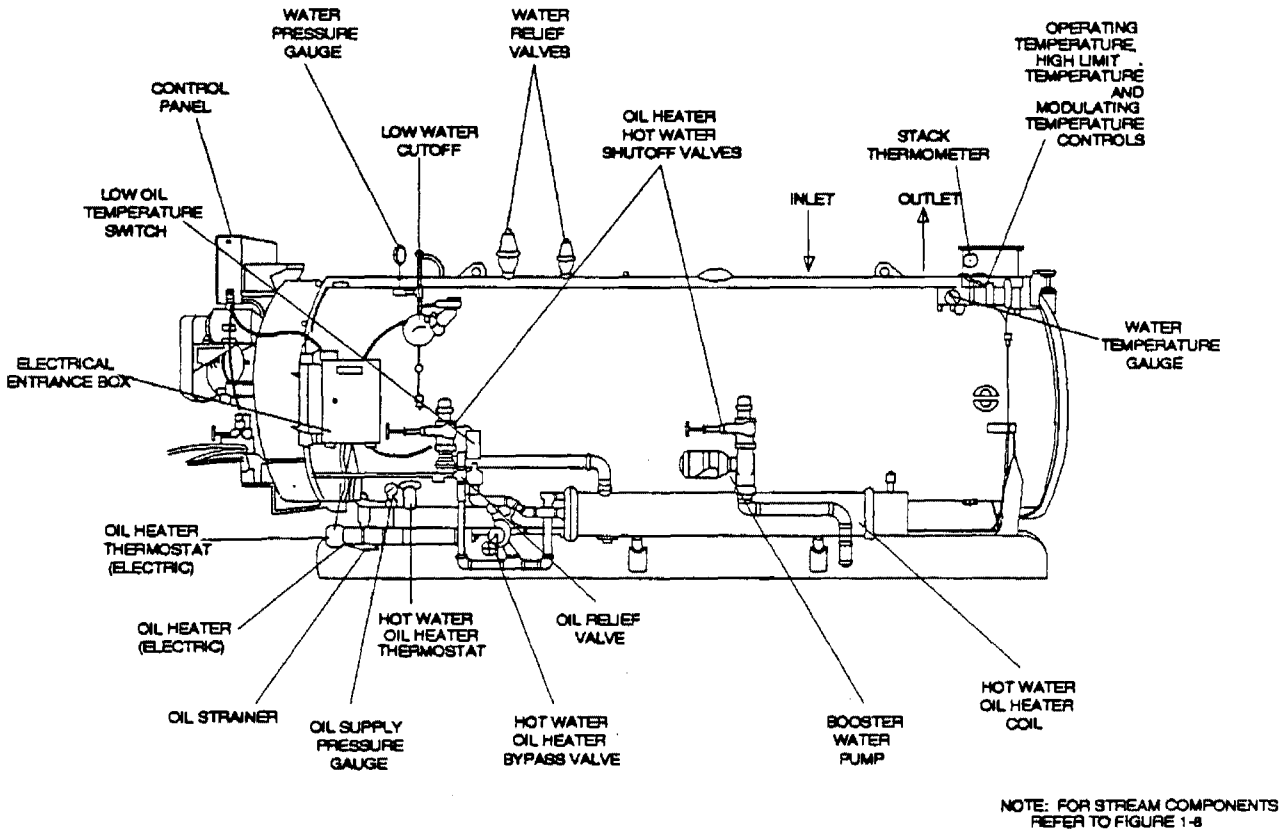
(1) Forced Draft Fan Motor (Fig. 1-1): Drives the forced draft fan directly to provide combustion air. Also referred to as a blower motor.

(2) Forced Draft Fan Motor Starter (Fig. 1-7): Energizes the forced draft fan (blower) motor.

(3) Forced Draft Fan (Fig. 1-10): Furnishes all air, under pressure, for combustion of pilot fuel and main fuel, and for purging.

(4) Ignition Transformer (Fig. 1-1): Provides a high voltage spark for ignition of the gas pilot or the light oil pilot.

(5) Modulating Motor (Fig. 1-1): Operates the rotary air damper and fuel valves through a cam and linkage system to provide proper air fuel ratios under all boiler load conditions.



[FIGURE 1-2 / TYPICAL HOT WATER BOILER WITH HEAVY OIL HEATER]

(6) Low Fire Switch (Not Shown): An internal auxiliary switch, cam actuated by the modulating motor shaft, which must be closed to indicate that the air damper and fuel metering valve are in the low fire position before an ignition cycle can occur.

(7) Burner Switch (Fig. 1-7): A manually operated start-stop switch for directly starting and stopping operation of burner.

(8) Manual-Automatic Switch (Fig. 1-7): When set at "automatic," subsequent operation is at the command of the modulating control, which governs the position of the modulating motor in accordance with load demand. When set at "manual," the modulating motor, through the manual flame control, can be positioned at a desired burner firing rate. The primary purpose of the manual position is for testing and setting the air-fuel ratio through the entire firing range.

(9) Manual Flame Control (Fig. 1-7): A manually operated potentiometer that permits the positioning of the modulating motor to a desired burner firing rate when the manual-automatic switch is set on manual. It is used primarily for initial or subsequent setting of fuel input throughout the firing range. It has no control over the firing rate when the manual-automatic switch is set on "automatic."

(10) Modulating Motor Transformer (located in the mod motor): Reduces control circuit voltage (115V AC) to required voltage (24V AC) for operation of the modulating motor.

(11) Indicator Lights (Fig. 1-7): Provide visual information on operation of the boiler as follows:

Flame Failure

Load Demand

Fuel Valve (valve open)

Low Water

(12) Program Relay and Flame Safe Guard Control (Fig. 1-7): Automatically programs each starting, operating and shutdown period in conjunction with operating limit and interlock devices. This includes, in a timed and proper sequence, the operation of the blower motor, ignition system, fuel valve(s), and the damper motor. The sequence includes air purge periods prior to ignition and upon burner shutdown.

The flame detector portion of this control monitors both oil and gas flames and provides protection in the event of the loss of a flame signal.

The control re-cycles automatically during normal operation or following a power interruption. It must be manually reset following a safety shut-down caused by a loss of flame. Incorporated is an internal checking circuit, effective on every start that will prevent burner operation in the event anything causes the flame relay to hold in during this period.

(13) Flame Detector (Fig. 1-1): Monitors gas or oil pilot and energizes the programmer's flame relay in response to a flame signal. It continues to monitor main flame (oil or gas) after expiration of pilot proving period. A standard equipped boiler has a lead sulfide (infrared sensitive) detector.

(14) Combustion Air Proving Switch (Fig. 1-1): A pressure sensitive switch actuated by air pressure from the forced draft fan. Its contacts close to prove the presence of combustion air. The fuel valves cannot be energized unless this switch is satisfied.

(15) Alarm (Not Shown): Sounds to notify the operator of a condition requiring attention. The alarm is available as optional equipment.

(16) Stack Thermometer (Fig. 1-1): Indicates the temperature of the vented flue gases.

(17) Diffuser (Figs. 1-4 and 1-10): This is a circular plate located at the furnace end of the burner drawer, which imparts a rotary swirling motion to combustion air immediately prior to its entering the furnace, thus providing for thorough and efficient mixing with the fuel.

(18) Rotary Air Damper (Figs. 1-4 and 1-10): This damper provides accurate control of combustion air in proportion to fuel input for various load demands. It consists of two concentric cylinders with openings. The outer is stationary. The inner is rotated, under control of the modulating motor, to vary the effective size of the openings where they overlap.

E. STEAM CONTROLS (ALL FUELS)

(1) Steam Pressure Gauge (Fig. 1-1): Indicates the pressure in the boiler.

(2) Operating Limit Pressure Control (Fig. 1-1): Breaks a circuit to stop the burner operation on a rise of boiler pressure above a selected setting. It is adjusted to stop or start the burner at a preselected pressure setting.

(3) High Limit Pressure Control (Fig. 1-1): Breaks a circuit to stop the 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. This control is normally equipped with a manual reset.

(4) Modulating Pressure Control (Fig. 1-1): Senses the changing boiler pressures and transmits this information to the modulating motor to change the burner's firing rate when the manual-automatic switch is set on automatic.

(5) Low Water Cutoff and Pump Control (Fig. 1-1): This float-operated control responds to the water level in the boiler. It performs two distinct functions:

(a) Stops the firing of the burner if the water level drops below a safe operating level and energizes the low water light in the control panel; it also causes the low water alarm bell (optional equipment) to ring. Code requirements of some models require a manual reset type of low water cutoff. This type requires manual resetting to start the burner after a low water shutdown.

(b) Starts and stops the feedwater pump (if used) to maintain water at the proper operating level.

CAUTION!

Determine that the main and auxiliary low water cutoffs and pump control are level after installation and throughout the equipment's operating life to avoid damage to the equipment.

(6) Auxiliary Low Water Cutoff (Not Shown) (Optional Equipment): This control breaks the circuit to stop the burner operation in the event the boiler water drops below the master low water cutoff point. Manual reset type (optional equipment) requires manual resetting in order to start the burner after a low water condition.

(7) Low Water Pump Control Instruction Plate (Fig. 7-1): Gives instructions and information for operation of low water devices.

(8) Water Column (Fig. 1-1): This assembly houses the low water cutoff and pump control and includes the water gauge glass, gauge glass shutoff cocks, and trycocks.

(9) Water Column Drain Valve (Fig. 1-1): 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 to keep the float bowl clean and free of sediment. A similar drain valve is furnished with the auxiliary low water cutoff (optional equipment) for the same purpose.

(10) Water Gauge Glass Drain Valve (Fig. 1-1): This valve is provided to flush the gauge glass.

(11) Test Valve (Fig. 1-1): This valve allows the boiler to be vented during filling, and facilitates routine boiler inspection.

(12) Safety Valve (Fig. 1-1): 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 safety valves and their escape piping shown in (Fig. 1-9) 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 build up of back pressure an 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 recommened (see Fig. 1-9). 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 covery any interior or working parts of the safety valve. A valve does not require any lubrication or protective coating to work properly.

!WARNING
Only properly certified personnel such as the safety valve manufacturer's certified representative should adjust or repair the boiler safety valves. Failure to heed this warning could result in serious personal injury or death.

F. HOT WATER CONTROLS (ALL FUELS)

(1) Water Temperature Gauge (Fig. 1-2): Indicates water temperature in the boiler.

(2) Water Pressure Gauge (Fig. 1-2): Indicates water pressure in the boiler.

(3) Operating Limit Temperature Control (Fig. 1-2): Breaks a circuit to stop the burner operation on a rise of boiler temperature above a selected setting. It is adjusted to stop or start the burner at a preselected operating temperature.

(4) High Limit Temperature Control (Fig. 1-2): Breaks a circuit to stop the burner operation on a rise of temperature above a selected setting. It is adjusted to stop the burner at a preselected temperature above the operating control setting. The high limit temperature control normally is equipped with a manual reset.

(5) Modulating Temperature Control (Fig. 1-2): Senses changing boiler temperature and transmits this information to the modulating motor to change the burner's firing rate when the manual-automatic switch is set on automatic.

(6) Low Water Cutoff (Fig. 1-2): Breaks the circuit to stop the burner operation if the water level in the boiler drops below a safe operating level, activating the low water light and optional alarm bell if the boiler is so equipped.

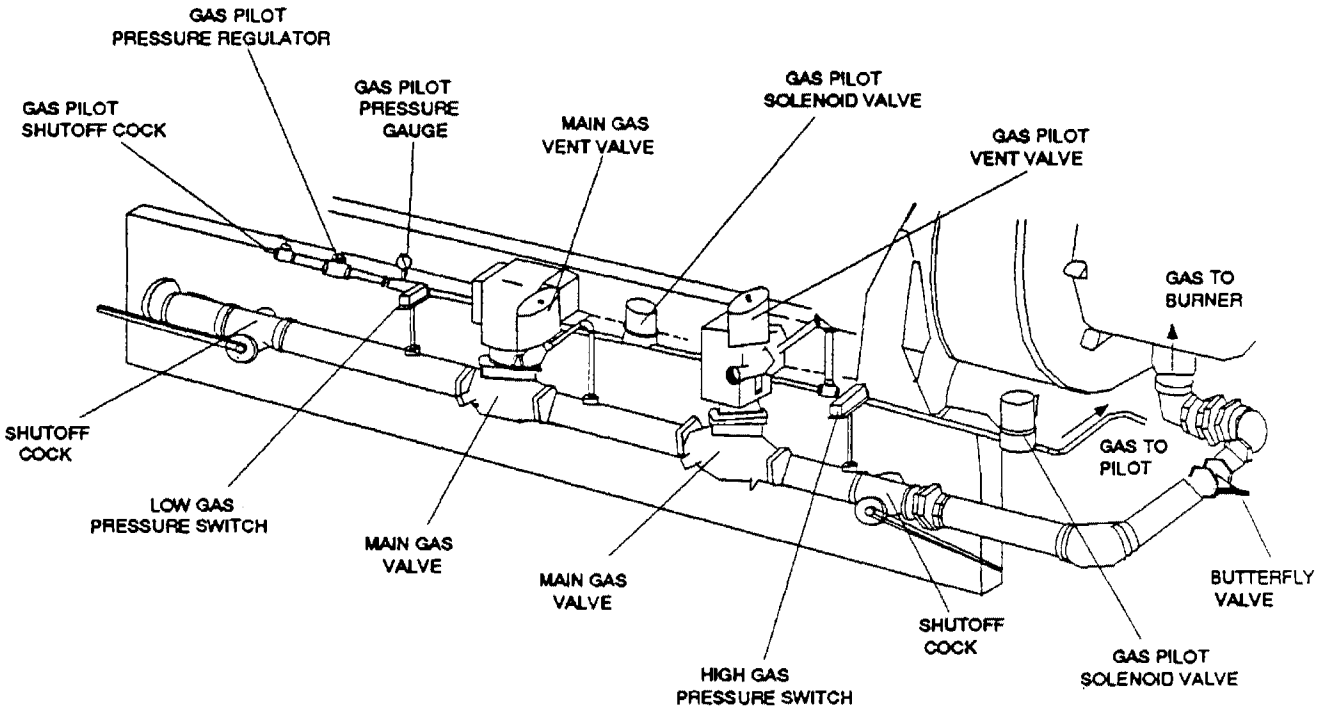
(7) Auxiliary Low Water Cutoff (Not Shown) (Optional): Breaks the circuit to stop the burner operation if the water level in the boiler drops below the master low water cutoff point.

(8) Relief Valve(s) (Fig. 1-2): Relief valve(s) relieve the boiler of pressure higher than the design pressure (or a lower pressure, if designated). Relief valves and their discharge piping are to be installed to conform to ASME code requirements.

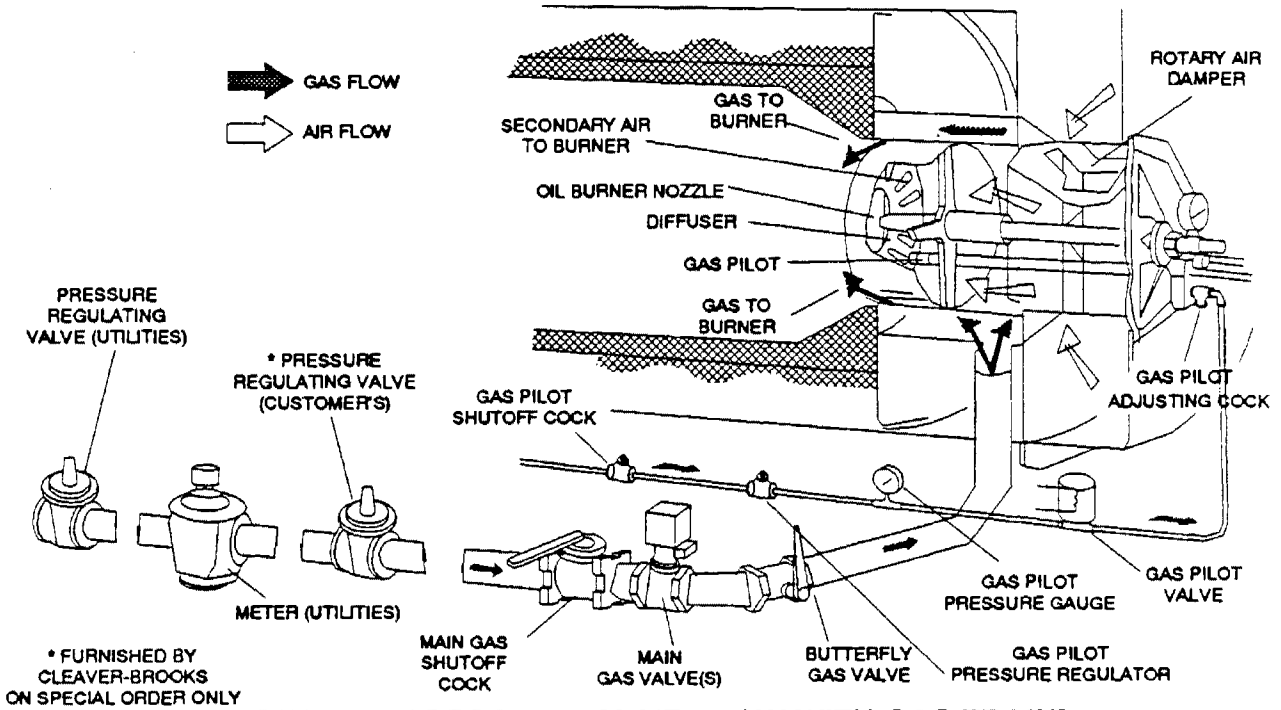
!WARNING
Only properly certified personnel such as the relief valve manufacturer's certified representative should adjust or repair the boiler relief valves. Failure to heed this warning could result in serious personal injury or death.

G. CONTROLS FOR GAS FIRING

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 the Dimension Diagram (DD) prepared by Cleaver-Brooks for your specific installation. A typical gas train is shown in Fig. 1-3.



[FIGURE 1-3 / TYPICAL GAS TRAIN]



[FIGURE 1-4 / SECONDARY AIR FLOW WITH GAS TRAIN]

(1) Gas Pilot Valve: A solenoid valve that opens during the ignition period to admit fuel to the pilot. It closes after main flame is established. The sequence of energizing and de-energizing is controlled by the programming relay. A second gas pilot valve may be required by insurance regulations.

(2) Gas Pilot Vent Valve: When a second gas pilot valve is required, a normally open vent valve is installed between them. Its purpose is to vent gas to the atmosphere, should any be present in the pilot line when the pilot valves are closed. The valve closes when the pilot valves are energized.

(3) Gas Pilot Shut-off Cock: For manually opening or closing the gas supply to the gas pilot valve.

(4) Gas Pilot Adjusting Cock (Fig. 5-10): Provided to regulate the size of the gas pilot flame.

(5) Gas Pilot Aspirator (Fig. 5-10): Improves the flow of gas to the pilot.

(6) Gas Pressure Gauge: Indicates gas pressure to the pilot.

(7) Gas Pressure Regulating Valve: Reduces incoming gas pressure to suit the pilot's requirement of between 5" to 10" W.C.

(8) Butterfly Gas Valve: The pivoted disc in this valve is actuated by connecting linkage from the gas modulating cam to regulate the rate of gas flow to the burner.

(9) Gas Modulating Cam (Fig. 5-6): An assembly of a series of adjustable allen-head screws and a contour spring, providing for adjustment of gas input at any point in the modulating range.

(10) Main Gas Cock: For manually opening and closing the main fuel gas supply downstream of the main gas line pressure regulator. 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.

(11) Main Gas Valves: Electrically actuated shut-off valves that open simultaneously to admit gas to the burner. The downstream valve is equipped with a "proof of closure" switch that is connected into the pre-ignition interlock circuit.

(12) Main Gas Vent Valve: A normally open solenoid valve installed between the two main gas valves to vent the 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.

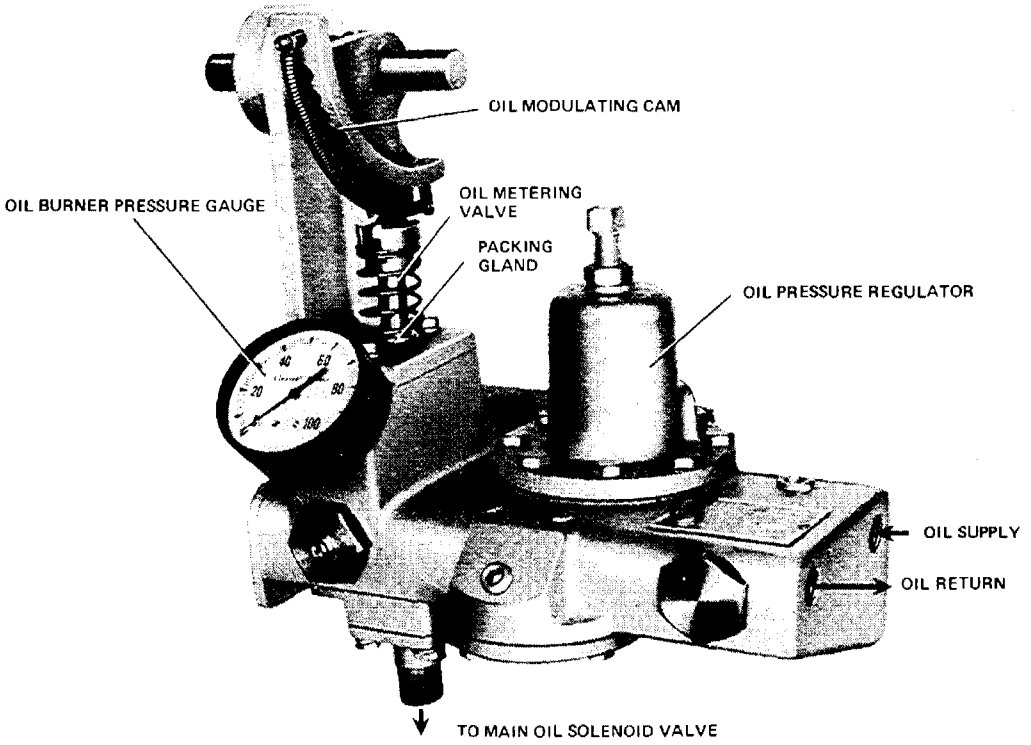
(13) Low Gas Pressure Switch: A pressure actuated switch that is closed whenever main gas line pressure is above a preselected pressure. Should the pressure drop below this setting, the switch contacts will open a circuit causing the main gas valve(s) to close, or prevent the burner from starting. This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

(14) High Gas Pressure Switch: A pressure actuated switch that is closed whenever the main gas line pressure is below a preselected pressure. Should the pressure rise above 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.

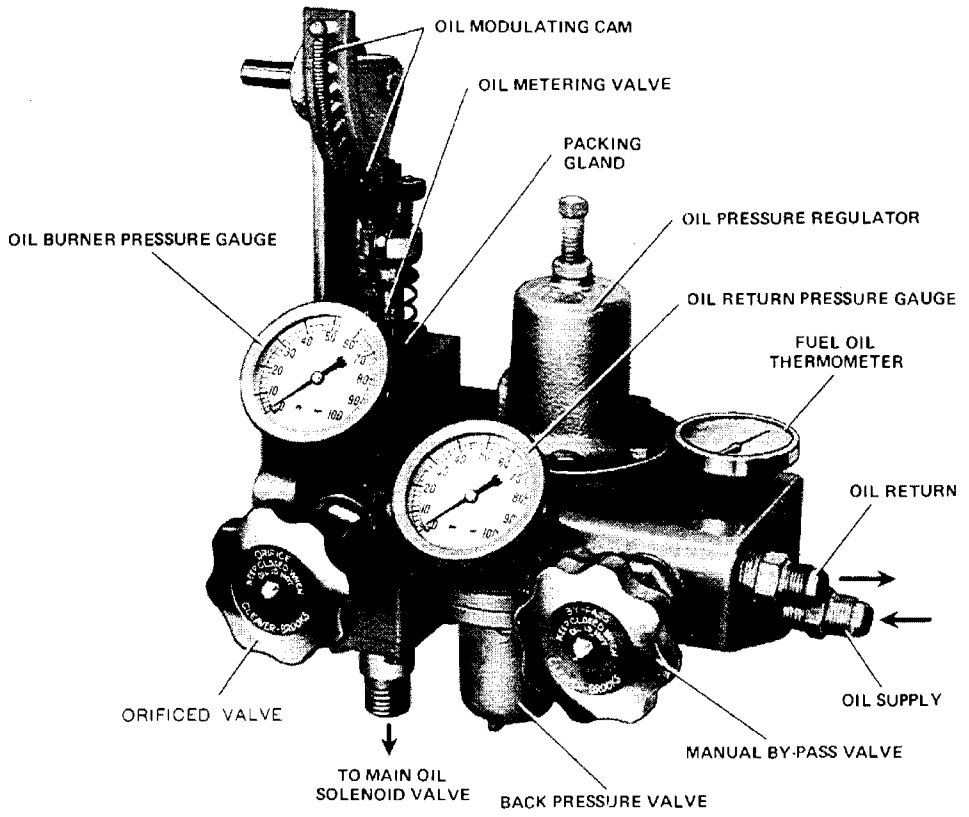
(15) Leakage Connection: The body of the gas valve has a plugged opening that is used whenever it is necessary or desirous to conduct a test for possible leakage across the closed valve.

H. CONTROLS COMMON TO OIL FIRED BOILERS (INCLUDING COMBINATION)

The following items are applicable to all oil fired or gas and oil fired boilers. Additional controls for No. 6 oil are listed in Section I.



[FIGURE 1-5 / OIL CONTROL VALVE ASSEMBLY - FOR LIGHT OIL]



[FIGURE 1-6 / OIL CONTROL VALVE ASSEMBLY - FOR HEAVY OIL]

(1) Oil Drawer Switch (Fig. 4-1): Opens the limit circuit if the oil drawer burner gun is not latched in the forward position required for burning oil.

(2) Atomizing Air Proving Switch (Fig. 1-1): Pressure actuated switch whose contacts are closed when sufficient atomizing air pressure from the air pump is present for oil firing. Oil valve(s) will not open or will not remain open unless the switch contacts are closed.

(3) Air Pump Module (Figs. 1-1 and 7-8): This assembly provides the compressed air required to atomize the fuel oil for proper combustion. It is started automatically by the programmer's sequence. It includes the components described below.

(a)Air Pump Motor (Fig. 7-8): This motor drives the air pump and an air cooling fan. The motor is started and stopped simultaneously with the forced draft fan motor.

(b)Air Pump (Fig. 7-8): Provides air for atomization of fuel oil.

(c)Air Filter (Fig. 7-8): An air inlet strainer to clean the air supply prior to entering the air pump.

(d)Check Valve (Figs. 1-11 and 1-12): Prevents lubricating oil and compressed air from surging back through the pump and air filter when the pump stops.

(e)Air-oil Receiver Tank (Fig. 7-8): Holds a supply of oil for lubricating the air pump and separates the lube oil from the atomizing air before delivery to the oil nozzle.

(f)Lube Oil Level Sight Glass (Fig. 7-8): Indicates the level of lubricating oil in the air-oil receiver tank.

(g)Lube Oil Cooling Coil (not shown): Cools the lubricating oil before it enters the air pump. A fan driven by the air pump motor circulates the cooling air over the coil.

(h)Lube Oil Fill Pipe and Strainer (Fig. 7-8): Used when adding oil to the air-oil receiver tank.

(4) Atomizing Air Pressure Gauge (Fig. 1-1): Indicates the atomizing air pressure at the burner gun.

(5) Low Oil Pressure Switch (Optional): Switch contacts open when fuel oil pressure drops below a selected pressure. The switch will interrupt the limit circuit upon loss of sufficient fuel oil pressure for correct combustion.

(6) Oil Solenoid Valve (Fig. 1-1): Opens when energized through contacts in the programmer and allows fuel oil flow from the oil metering valve to the burner nozzle. A light oil fired burner uses two valves operating simultaneously.

(7) Fuel Oil Controller (Figs. 1-1 and 1-5): An assembly combining into a single unit the gauges, regulators and valves required for regulating the flow of fuel oil. All controllers have the following integral parts. In addition to these, the controller used on a No. 6 oil fired burner has additional components described in Section I.

(a)Oil Metering Valve: The valve metering stem moves to increase or decrease the orifice area to regulate the supply of fuel oil to the burner nozzle in accordance with boiler load variances. Stem move-

ment is controlled by the modulating motor through linkage and the oil metering cam.

(b)Oil Modulating Cam: An assembly consisting of a series of adjustable allen-head screws and a contour spring providing for adjustment of oil input at any point in the modulating range.

(c)Oil Burner Pressure Gauge: Indicates pressure of the fuel oil at the metering valve.

(d)Oil Pressure Regulator: For adjustment of the oil pressure at the metering valve.

(8) Fuel Oil Pump (Not Shown): Transfers fuel oil from the storage tank and delivers it under pressure to the burner system.

(9) Oil Relief Valve (Fig. 1-1): Maintains a constant oil supply pressure to the fuel oil controller by bypassing excess fuel oil.

(10) Fuel Oil Strainer (Fig. 1-1): Provided to prevent foreign matter from entering the burner system.

(11) Gas Pilot: See Section G for description of the various components.

(12) Light Oil Pilot Valve (Not Shown): When a light oil pilot is furnished, a solenoid valve is provided to control the flow of fuel to the pilot nozzle. It is energized through programmer contacts. It is de-energized to shut off pilot fuel flow after main flame is ignited and established.

(13) Back Pressure Orifice (Fig. 1-1): A restriction located in the oil return line immediately downstream of the fuel oil controller to create back pressure (100 and 200 series only).

I. ADDITIONAL CONTROLS FOR HEAVY OIL

NOTE: Items 6 and 7 are applicable only on a hot water boiler.

(1) Oil Heater Switch (Fig. 1-7): Manually provides power to the oil heater system.

(2) Oil Heater (Electric) (Figs. 1-2 and 1-8): Used for heating sufficient fuel oil for low fire flow during cold starts before steam or hot water is available for heating. The heater must be turned off during extended boiler lay-up, or any time that the fuel oil transfer pump is stopped.

(3) Oil Heater (Steam/Hot Water) (Figs. 1-2 and 1-8): Heats fuel oil through the medium of steam or hot water. The electric heater is housed in the steam heater, but is housed separately on a hot water heater. Steam oil heaters on 15 psi boilers will operate at boiler pressure. Steam oil heaters furnished on high pressure boilers are also to be operated at less than 15 psi. This is accomplished through use of a steam pressure regulator valve.

(4) Electric Oil Heater Thermostat (Figs. 1-2 and 1-8): Senses the fuel oil temperature and energizes or de-energizes the electric oil heater to maintain the required temperature of the fuel oil.

(5) Steam Oil Heater Thermostat (Fig. 1-8): Senses the fuel oil temperature and controls the opening and closing of the steam heater valve to maintain the required temperature of the fuel oil.

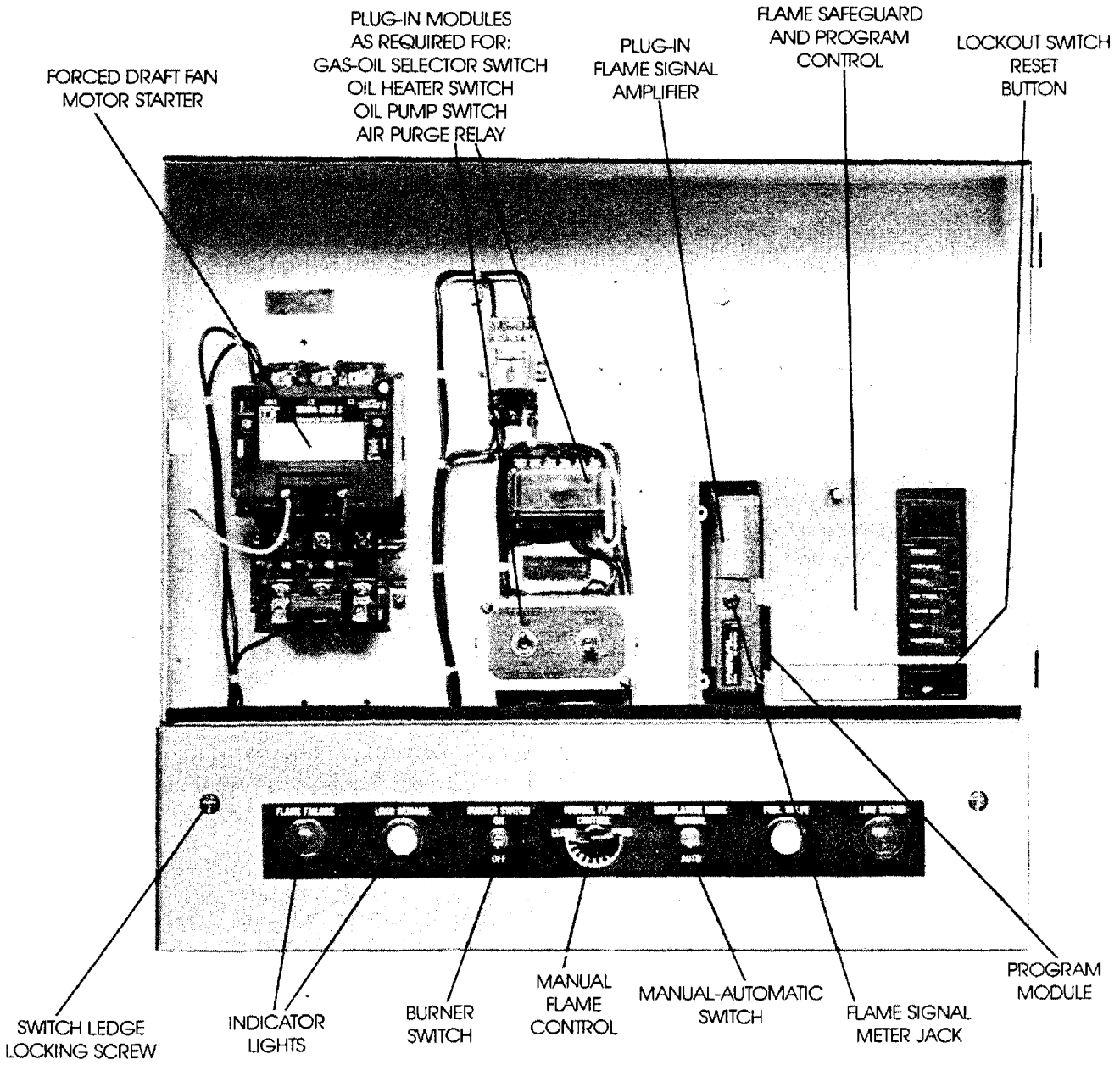
(6) Hot Water Oil Heater Thermostat (Fig. 1-2): This control is used on a hot water boiler to sense the fuel oil temperature and control the starting and stopping of the booster water pump to supply hot water to the pre-heating assembly to maintain the required temperature of the fuel oil.

(7) Booster Water Pump (Fig. 1-2): Started and stopped by the hot water thermostat to regulate the flow of hot water through the hot water oil heater to maintain the temperature of the fuel oil.

(8) Oil Heater Steam Valve (Fig. 1-8): A normally closed solenoid valve opened by the steam oil heater thermostat to allow the flow of steam to the steam heater to maintain the temperature of the fuel oil.

(9) Steam Heater Check Valve (Fig. 1-8): Prevents oil contamination of the waterside of the pressure vessel should any leakage occur in the oil heater.

(10) Steam Heater Pressure Regulator (Fig. 1-8): Adjust to provide reduced (usually less than 15 psi) steam pressure to the heater to properly maintain the required fuel oil temperature. This regulator and the pressure gauge are not furnished on 15 psi units.



[FIGURE 1-7 / TYPICAL CONTROL PANEL]

(11) Steam Trap (Fig. 1-8): Drains condensate and prevents the loss of steam from the steam oil heater. Condensate must be piped to a safe point of discharge.

(12) Check Valve (Steam Heater Discharge) (Fig. 1-8): Prevents air entry during shutdown periods when cooling action may create a vacuum within the steam heater.

(13) Oil Supply Pressure Gauge (Figs. 1-2 and 1-8): Indicates fuel oil pressure in the oil heater and supply pressure to the fuel oil controller's pressure regulator.

(14) Low Oil Temperature Switch (Figs. 1-2 and 1-8): Thermostatic switch that prevents the burner from starting, or stops the burner from firing if the selected fuel oil temperature is lower than is required for proper oil burner operation.

(15) High Oil Temperature Switch (Not Shown) (Optional): The switch contacts open when the fuel oil temperature rises above a selected temperature. The switch will interrupt the limit circuit in the event the fuel oil temperature rises above the selected point.

(16) In addition to the components of the fuel oil controller mentioned in Section H, the following are used with a heavy oil fired burner.

(a)Fuel Oil Thermometer: Indicates the temperature of fuel oil being supplied to the fuel oil controller.

(b)Back Pressure Valve: For the adjustment of the oil pressure on the downstream side of the metering valve. Also regulates the rate of return oil flow.

(c)Oil Return Pressure Gauge: Indicates the oil pressure on the return side of the fuel oil controller.

(d)Manual By-Pass Valve: Provided as a time saver in establishing oil flow. When open, it permits the circulation of oil through the supply and return lines. During operation, this valve must be closed.

(e)Orifice Oil Control Valve: The valve may be opened prior to start-up to aid in establishing fuel oil flow through the controller. Prior to the initial light off, this valve must be closed. Its disc has an orifice to permit a continuous circulation of hot fuel oil through the controller.

(17) Air Purge Valve (Not Shown): The solenoid valve opens simultaneously with the closing of the oil solenoid valve at burner shutdown, allowing compressed air to purge oil from the burner nozzle and adjacent piping. This oil is burned by the diminishing flame, which continues burning for approximately 4 seconds after the oil solenoid valve closes.

(18) Air Purge Orifice Nozzle (Not Shown): Limits purging air to the proper quantity for expelling unburned oil at normal delivery rate.

(19) Air Purge Orifice Nozzle Filter (Not Shown): Filters the purging air of any particles that might plug the air purge orifice nozzle.

(20) Air Purge Check Valve (Not Shown): The check valve prevents the fuel oil from entering the atomizing air line.

(21) Air Purge Relay (Fig. 1-7): When energized, controls operation of the air purge valve.

J. CONTROLS FOR COMBINATION BURNERS ONLY

(1) Gas-Oil Switch (Fig. 1-7): Burners equipped to burn either oil or gas include equipment for each fuel. The selector switch engages the appropriate interlocks and controls for gas or oil operation. Chapter 4 details the required mechanical functions of each fuel system.

K. COMBUSTION AIR

Air for combustion of fuel (often referred to as "secondary" air) is furnished by the forced draft fan (Fig. 1-10) mounted in the boiler head. In operation, air pressure is built up in the entire head and is forced through a diffuser plate for a thorough mixture with the fuel for proper combustion. The supply of secondary air to the burner is governed by automatically throttling the output of the fan by regulating the rotary air damper. This furnishes the proper amount of air for the correct ratio of air to fuel for efficient combustion at all firing rates.

L. AUTOMATIC IGNITION

Oil or gas burners are ignited by an interrupted type pilot. The pilot flame is ignited automatically by an electric spark.

A series 100 burner usually is equipped with a pilot fired with light oil fuel. All other burners, as well as a series 100 burner complying with insurance underwriters requirements, are equipped with a gas burning pilot. In the case of a combination burner, the gas pilot is used to ignite either the main gas flame or the oil flame. Either pilot serves the same function and unless exception is taken in the text, the term pilot is used interchangeably.

At the beginning of the ignition cycle, and governed by the program relay, the pilot solenoid valve and ignition transformer are simultaneously energized.

The ignition transformer supplies high voltage current for the igniting spark. A gas pilot has a single electrode and a spark arcs between the tip of the electrode and the wall of the tube surrounding it. A light oil pilot has two electrodes and the arc is between their tips. The pilot solenoid valve and the transformer are de-energized after the main flame is ignited and established.

Fuel for the gas pilot is supplied from the utility's main or from a tank (bottle) supply. Secondary air flows into and mixes with the pilot gas stream to provide an adequate flame.

Insurance regulations may require two gas pilot solenoids with a normally open vent valve between them. The vent valve closes when the gas pilot valves open, and opens when the gas pilot valves shut to vent gas should any be present in the pilot line during the de-energized period of the gas pilot valves.

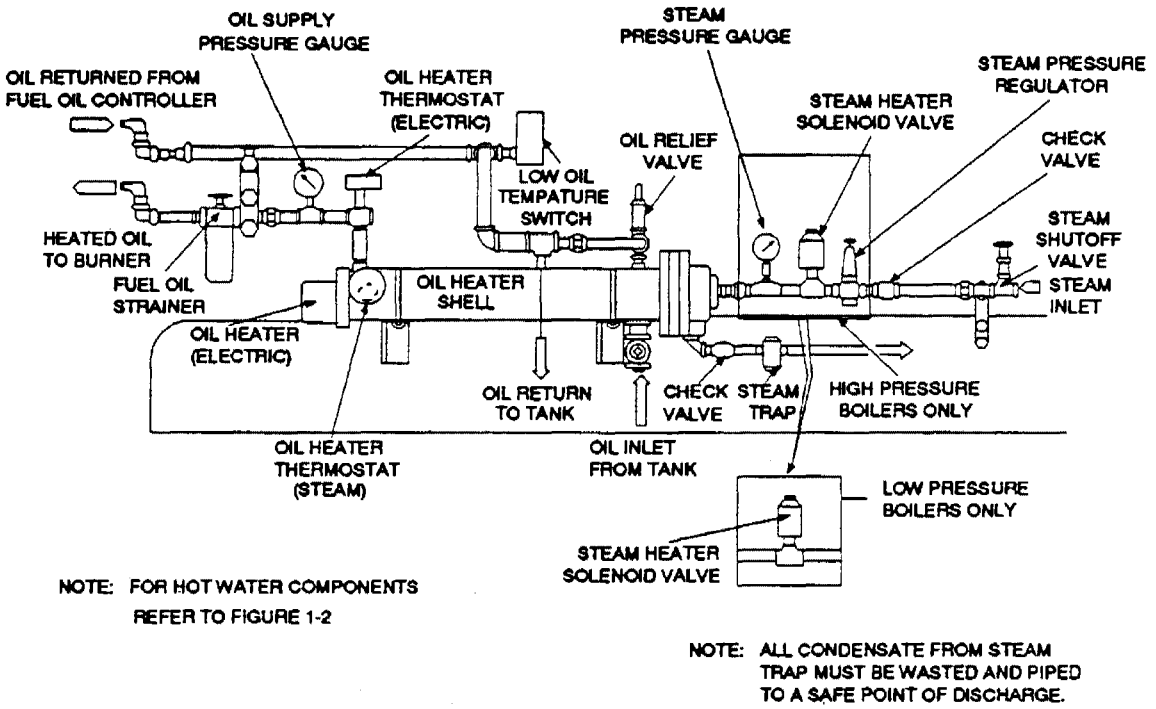
Fuel for a light oil pilot is provided from the line that supplies oil under pressure for the main flame. A solenoid actuated valve controls the flow of oil to the pilot nozzle. This valve is energized simultaneously with the ignition transformer at the beginning of the ignition cycle and is de-energized after the main flame is ignited and established.

M. ATOMIZING AIR

Air for atomizing the fuel oil (often referred to as "primary air") is pumped by the air pump into the air-oil receiver tank and delivered under pressure through a manifold block to the oil burner nozzle.

The atomizing air mixes with the fuel oil just prior to the oil leaving the nozzle.

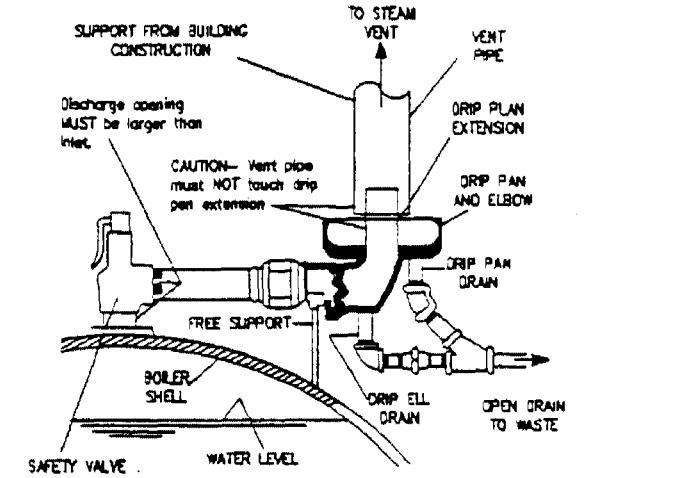
Atomizing air pressure is indicated by the air pressure gauge on the burner gun.



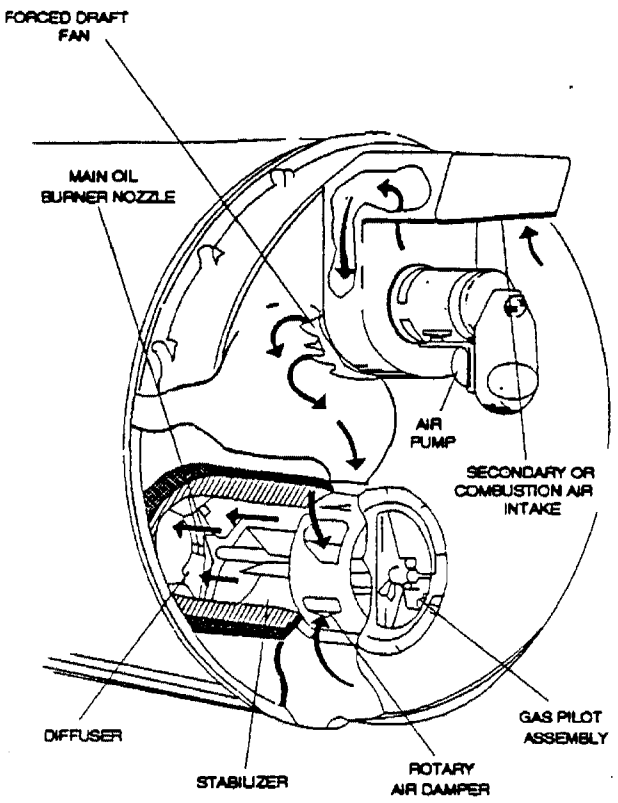
[FIGURE 1-8 / OIL HEATING ASSEMBLY (STEAM)]

Air pressure from the pump also forces sufficient oil from the tank to the pump bearings to lubricate them and also to provide a seal and lubrication for the pump vanes. As a result, the air delivered to the tank contains some lube oil; however, most of it is recovered through baffles and filters in the tank before the air passes to the burner.

Some of the primary air also is used to assist the oil pressure regulators of the fuel oil controller. This is explained in Chapter 4.



[FIGURE 1-9 / RECOMMENDED SAFETY VALVE INSTALLATION PROCEDURE]



[FIGURE 1-10 / SECONDARY AIR FLOW DIAGRAM]

N. OIL FUEL FLOW - LIGHT OIL

The oil fuel flow system is shown in schematic diagram in Fig. 1-11. Oil flow is indicated by arrows and the pertinent controls are called out. Fuel oil is delivered into the system by a supply pump that delivers part of its discharge to the oil burner. Excess oil is returned to the oil storage tank through the fuel oil relief valve and oil return line. Normally, the pump operates only while the burner is in operation, although often a positioning switch is provided so that either continuous or automatic pump operation can be obtained.

The oil flows through a fuel oil strainer provided to prevent any foreign material from flowing through the control valves and nozzle. The fuel oil controller contains in a single unit,a metering valve, a regulator, and a gauge required to regulate the pressure and flow of oil to the burner. The adjustable regulator controls the pressure. To assist in this regulation, back pressure is created by an orifice nozzle located in the oil return line immediately downstream of the fuel oil controller.

The programming relay energizes or de-energizes the solenoid oil valves to permit or cut off oil flow to the burner. Two valves, operating simultaneously, are used. These valves are closed when de-energized. They cannot be opened (energized) unless the combustion air proving switch and the atomizing air proving switch are closed. These are satisfied, respectively, by sufficient combustion air pressure from the forced draft fan and pressurized air from the air pump.

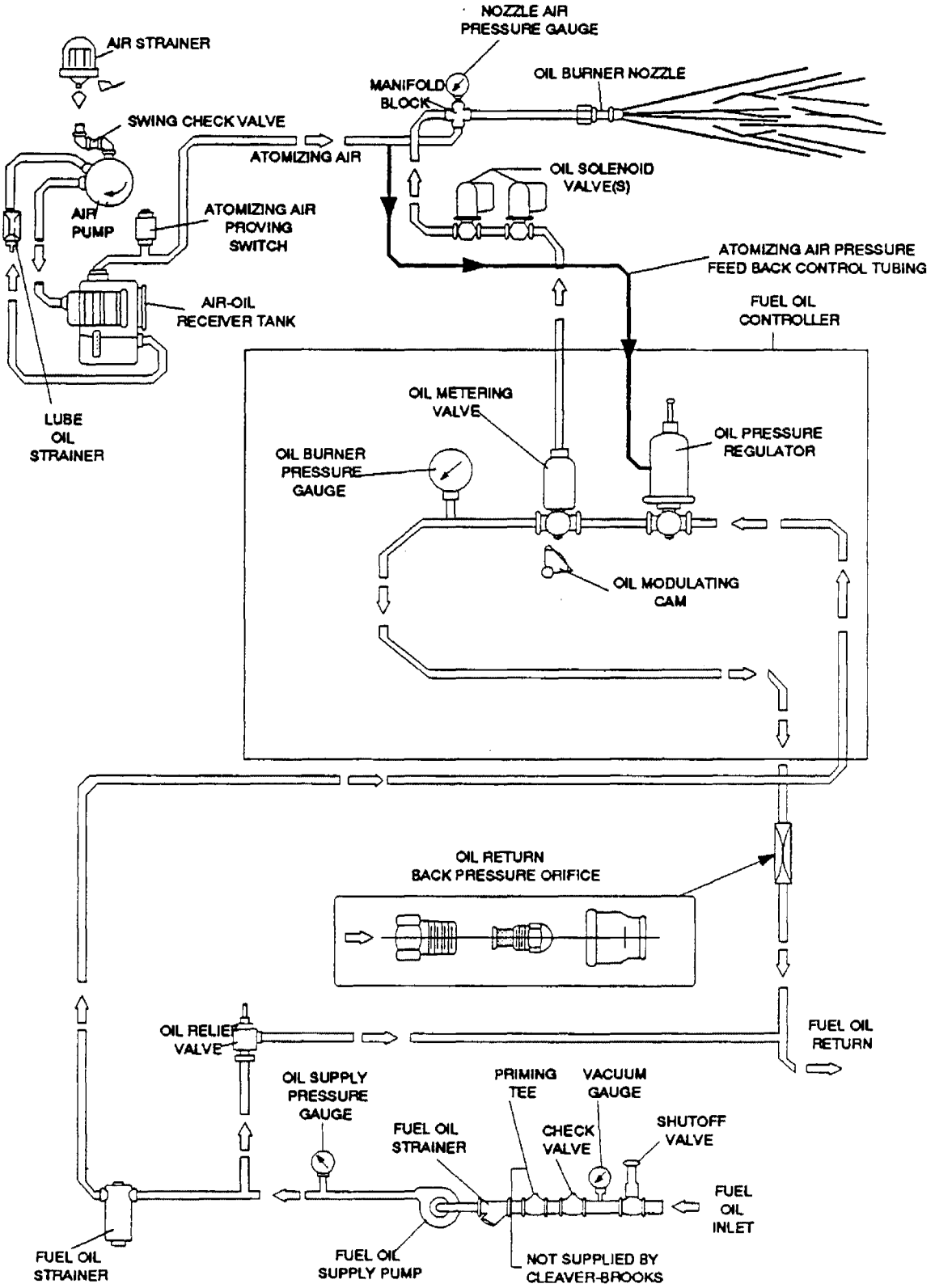
The oil flow to the burner is controlled by the movement of the metering stem in the oil metering valve, which varies the flow to meet load demands. The metering valve and the air damper are controlled simultaneously at all times by the modulating motor to proportion combustion air and fuel for changes in load demand.

O. OIL FUEL FLOW – HEAVY OIL

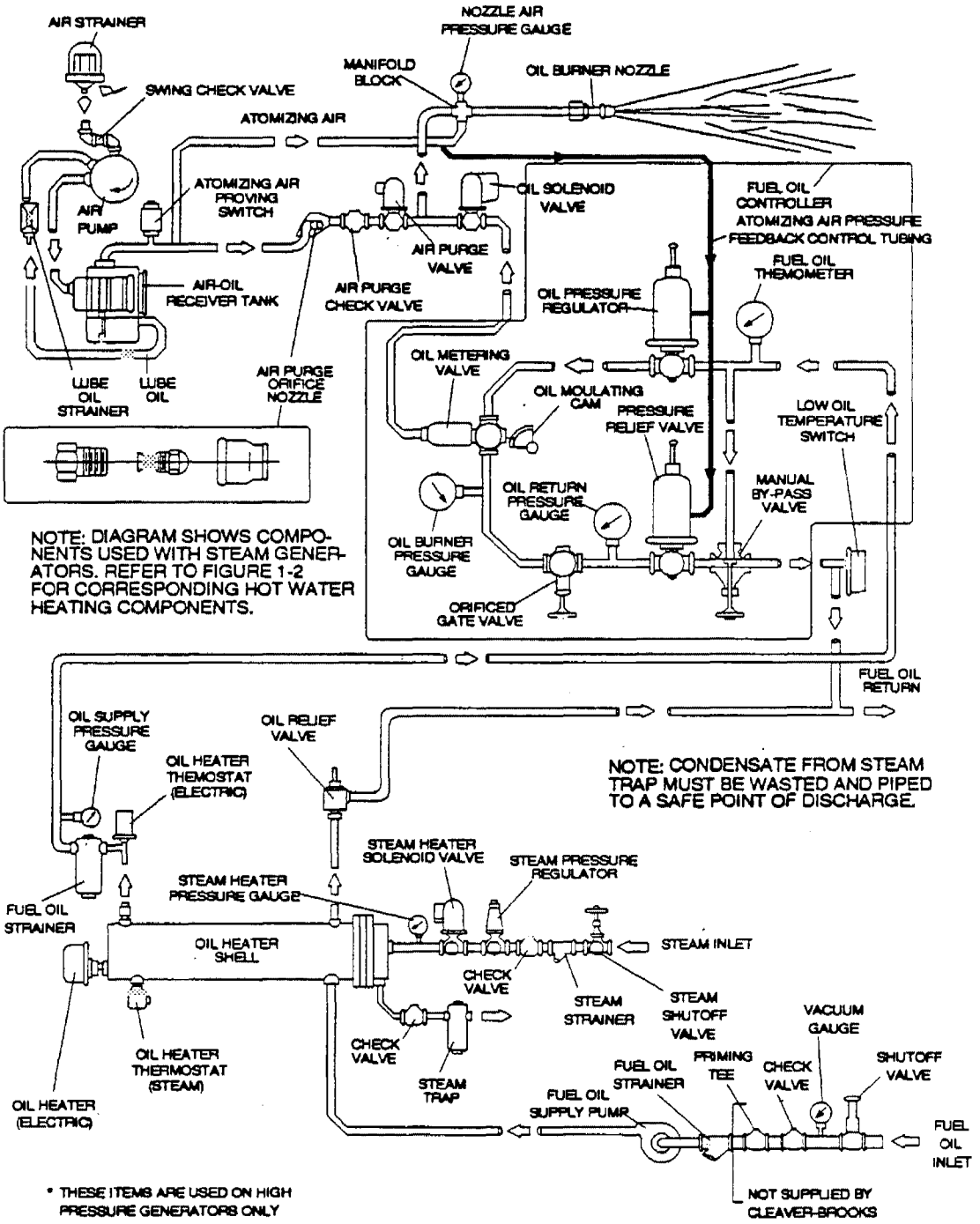
The oil fuel flow and circulating system is shown in the schematic diagram in Fig. 1-12. The pertinent controls are called out and the oil flow is indicated by arrows.

Fuel oil is delivered into the system by the fuel oil supply pump, which delivers part of its discharge to the oil heater. The remainder of the fuel oil returns to the oil storage tank through a fuel oil relief valve and oil return line.

The combination electric and steam oil preheater is controlled by thermostats. The electric oil heater thermostat energizes the electric heater



[FIGURE 1-11 / SCHEMATIC DIAGRAM FOR LIGHT OIL FLOW]



[FIGURE 1-12 / SCHEMATIC DIAGRAM FOR NO. 6 HEAVY OIL FLOW (STEAM-ELECTRIC HEATER)]

that is provided to supply heated oil on cold starts. The steam heater thermostat controls the operation of the steam solenoid valve to permit a flow of steam to the heater when steam is available.

A hot water boiler is equipped to heat the oil with hot water from the boiler unless other pre-heating equipment is utilized. The electric heater, which is housed separately, is sized to provide heated oil on a cold start. The hot water thermostat controls the operation of a pump that supplies hot water to the oil heater when hot water is available.

The heated oil flows through a fuel oil strainer to prevent any foreign matter from entering the control valves and nozzle.

The fuel oil controller contains in a single unit the necessary valves, regulators and gauges to regulate the pressure and flow of oil to the burner.

The program relay energizes or de-energizes the solenoid oil valve to permit or cut off oil flow to the burner. The oil solenoid is closed when de-energized. It cannot be opened (energized) unless the combustion air proving switch, the atomizing air proving switch and the low oil temperature and any pressure switches are closed. These are satisfied, respectively, by sufficient combustion air pressure from the forced draft fan, pressurized air from the air pump and sufficient oil temperature and pressure.

Oil flow to the burner is controlled by the movement of the metering stem of the oil metering valve, which varies the flow to meet load demands. The metering valve and the air damper are controlled simultaneously at all times by the modulating motor to proportion combustion air and fuel for changes in load demand.

Oil is purged from the burner gun upon each burner shut down. The air purge solenoid valve opens as the fuel valve closes and diverts atomizing air through the oil line. This assures a clean nozzle and line for the subsequent restart.

P. GAS FUEL FLOW

The gas flow system is shown in Fig. 1-4. Gas flow is indicated by arrows and the pertinent controls are shown. Combustion air travel is also shown and indicated by a different type of arrow.

Metered gas from the utility flows through the pressure regulator at a reduced pressure suitable to the burner's requirements, through the main gas shut-off cock, main gas valve(s) and modulating butterfly gas valve to the non-premix orifice type burner.

The main gas valve is of the normally closed type and is opened (energized) in proper sequence by the programming relay.

The butterfly gas valve modulates the flow of gas from low through high fire settings. The position of the butterfly valve disc is governed by the gas modulating cam. The butterfly gas valve, and the air control damper are controlled simultaneously by the modulating motor to proportion combustion air and fuel for changes to load demand.

The gas flow rate required for rated burner input depends upon the heating value (BTU/cubic foot) of the gas supplied. The gas pressure regulator adjusts the gas pressure (flow rate) to the entrance of the gas train. The regulator is not always supplied with the burner, but may be provided by others.

The main gas valves cannot be energized (opened) unless the combustion air proving switch is closed to indicate a sufficient supply of combustion air. The low gas pressure and high gas pressure switches must be closed to prove sufficient, but not excessive, gas fuel pressure.

Q. MODULATING FIRING

The modulating motor, through a linkage arrangement, controls the air damper and the butterfly gas valve or the oil metering valve to maintain a constant air-fuel ratio throughout the firing range.

During burner operation, the motor is controlled by a modulating pressure control on a steam boiler, or by a modulating temperature control on a hot water boiler. A manually operated potentiometer is provided to permit the positioning of the motor at a desired burner firing rate. This is used primarily for initial or subsequent checking and setting of fuel input. Normal operation should be with the manual-automatic switch in the "automatic" position and under the control of the modulating control.

The modulating motor (commonly called a damper motor) is reversible. It has an internal limit switch that restricts shaft rotation to 90°. During normal operation the motor will move in either direction or stop at any position within this range.

The motor's potentiometer is electrically connected to a matching potentiometer in the modulating control. Changing steam pressure or water temperature alters the electrical resistance of the modulating controller's potentiometer. This change in resistance compels an integral balancing relay to start, stop, or reverse the motor rotation. Rotation in either direction continues until the resistance ratio of the two potentiometers are equal.

When this occurs, the motor stops in a position that allows the proper fuel and combustion air flow to meet operating demands.

A feature designed into the circuitry is that the modulating motor must be in the low fire position during ignition and remain there until the main flame is established. A low fire switch, integral to the motor, is actuated by the rotation of the motor. The switch must be closed to establish that the damper and fuel metering valves are in low fire position before the programmer commences into the ignition period. During this time, neither the manual flame control nor the modulating control have any control over the damper motor, regardless of their setting.

An optionally equipped boiler has a second integral switch used to establish that the motor has driven the damper to an open position during the pre-purge period. This switch closes, as high fire position is approached, to complete an internal circuit in the programmer and allow continuation of the programming cycle.

CHAPTER 2

THE PRESSURE VESSEL

A. GENERAL

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

The type of service that your boiler is required to provide has an important bearing in the amount of waterside care it will require.

Although it is of prime importance, the subject of water supply and treatment cannot adequately be covered in this manual. For specific information or assistance with your water treatment requirements, contact your Cleaver-Brooks service and parts representative.

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

Water requirements for both steam and hot water boilers are essential to boiler life and length of service. Constant attention to this area will pay dividends in the form of longer life, less downtime, 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.

The operator should be familiar with this chapter before attempting to place the unit into operation.

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

B. CONSTRUCTION

Those steam boilers designed for 15 psig and hot water boilers designed for 250°F at 125 psi or less are constructed in accordance with Section IV, Power Boilers, of the ASME Code.

Those steam boilers designed for operation exceeding 15 psig are constructed in accordance with Section I, Power Boilers, of the ASME Code. Hot water boilers for operation over 250°F or 125 psi are likewise built to this Code.

C. WATER REQUIREMENTS

1. Hot Water Boiler

Air Removal
The hot water outlet includes a dip tube which extends 2 to 3 inches into the boiler. This dip tube reduces the possibility of any air which may be trapped at the top of the shell from entering into the system.

Any oxygen or air which is released in the boiler will collect or be trapped at the top of the boiler shell.

The air vent tapping on the top center line of the boiler should be piped into the expansion or compression tank. Any air that is trapped at the top of the boiler will find its way out of the boiler through this tapping.

Minimum Boiler Water Temperature — The minimum recommended operating boiler water temperature is 170°F. When water temperatures lower than 170°F are used, the combustion gases are reduced in temperature to a point where the water vapor condenses. The net result is that corrosion occurs in the boiler and breeching.

This condensation problem is more severe on a unit that operates intermittently and that is greatly 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. However, this problem can be minimized by maintaining boiler water temperatures above 170°F.

Another reason for maintaining boiler water temperature above 170°F is to provide a sufficient temperature "head" when No. 6 fuel oil is to be heated to the proper atomizing temperature by the boiler water in a safety type oil preheater. (The electric preheater on the boiler must provide additional heat to the oil if boiler water temperature is not maintained above 200°F.)

CAUTION!

If the operating water temperature going to the system must be lower than 170°F, the operating boiler water temperature should be a minimum of 170°F (200°F if used to preheat No. 6 oil) and mixing valves should be used to avoid damage to the equipment.

Rapid Replacement of Boiler Water — The system layout and controls should be arranged to prevent the possibility of pumping large quantities of cold water into a hot boiler, thus causing shock or thermal stresses. A formula, or "magic number," cannot be given, but it should be borne in mind that 200°F or 240°F water in a boiler cannot be completely replaced with 80°F water in a few minutes time without causing thermal stress. This applies to periods of "normal operation," as well as during initial start-up.

Boiler Size (BHP)	Boiler Output (1000) Btu/Hr	System Temperature Drop — Degrees F									
		10	20	30	40	50	60	70	80	90	100
		Maximum Circulating Rate — GPM									
15	500	100	50	33	25	20	17	14	12	11	10
20	670	134	67	45	33	27	22	19	17	15	13
30	1,005	200	100	67	50	40	33	29	25	22	20
40	1,340	268	134	89	67	54	45	38	33	30	27
50	1,675	335	168	112	84	67	56	48	42	37	33
60	2,010	402	201	134	101	80	67	58	50	45	40
70	2,345	470	235	157	118	94	78	67	59	52	47
80	2,680	536	268	179	134	107	90	77	67	60	54
100	3,350	670	335	223	168	134	112	96	84	75	67
125	4,185	836	418	279	209	168	140	120	105	93	84
150	5,025	1,005	503	335	251	201	168	144	126	112	100
200	6,695	1,340	670	447	335	268	224	192	168	149	134
250	8,370	1,675	838	558	419	335	280	240	210	186	167
300	10,045	2,010	1,005	670	503	402	335	287	251	223	201
350	11,720	2,350	1,175	784	587	470	392	336	294	261	235
400	13,400	2,680	1,340	895	670	535	447	383	335	298	268
500	16,740	3,350	1,675	1,120	838	670	558	479	419	372	335
600	20,080	4,020	2,010	1,340	1,005	805	670	575	502	448	402
700	23,430	4,690	2,345	1,565	1,175	940	785	670	585	520	470
800	26,780	5,360	2,680	1,785	1,340	1,075	895	765	670	595	535

[FIGURE 2-1 / CIRCULATION CHART]

CAUTION!

The circulating pump should be interlocked with the burner so that the burner cannot operate unless the circulating pump is running to avoid damage to the equipment.

When individual zone circulating pumps are used, it is recommended that they be kept running — even though the heat users do not require hot water. The relief device or by-pass valve thus will allow continuous circulation through the boiler and will help prevent rapid replacement of boiler water with "cold" zone water.

Continuous Flow Through the Boiler — The system should be piped and the controls so arranged that there will be water circulation through the boiler under all operating conditions. The operation of three-way valves and system controls should be checked to make sure that the boiler will not be by-passed. Constant circulation through the boiler eliminates the possibility of stratification within the unit and results in more even water temperatures to the system.

A rule of thumb of ½ to 1 GPM per boiler horsepower can be used to determine the minimum continuous flow rate through the boiler under all operating conditions.

The operator should determine that a flow of water exists through the boiler before initial firing or refiring after the boiler has been drained.

Water Circulation
The chart in Fig. 2-1 shows the maximum GPM circulation rate of boiler water in relation to full boiler output and system temperature drop.

Multiple Boiler Installations — When multiple boilers of equal or unequal size are used, care must be taken to ensure adequate or proportional flow through the boilers. This can best be accomplished by use of balancing cocks and gauges in the supply line from each boiler. If balancing cocks or orifice plates are used, a significant pressure drop (e.g., 3-5 psi) must be taken across the balancing device to accomplish this purpose.

If care is not taken to ensure adequate or proportional flow through the boilers, this can result in wide variations in firing rates between the boilers.

In extreme cases, one boiler may be in the high fire position, and the other boiler or boilers may be at low fire. The net result would be that the common header water temperature to the system would not be up to the desired point. This is an important consideration in multiple boiler installations.

Pressure Drop Through Boiler — There will be a pressure drop of less than three feet head (1 psi - 2.31 ft. hd.) through all standard equipped Cleaver-Brooks boilers operating in any system which has more than a 10°F temperature drop.

Pump Location — It is recommended that the system circulating pumps take suction from the outlet connection on the boiler and that they discharge to the system load. This puts the boiler and the expansion tank on the suction side of the pump. This location is preferred because it decreases air entry into the system and does not impose the system head on the boiler.

It is common practice to install a standby system circulating pump. The main circulating pump usually is located adjacent to the boilers in the boiler room.

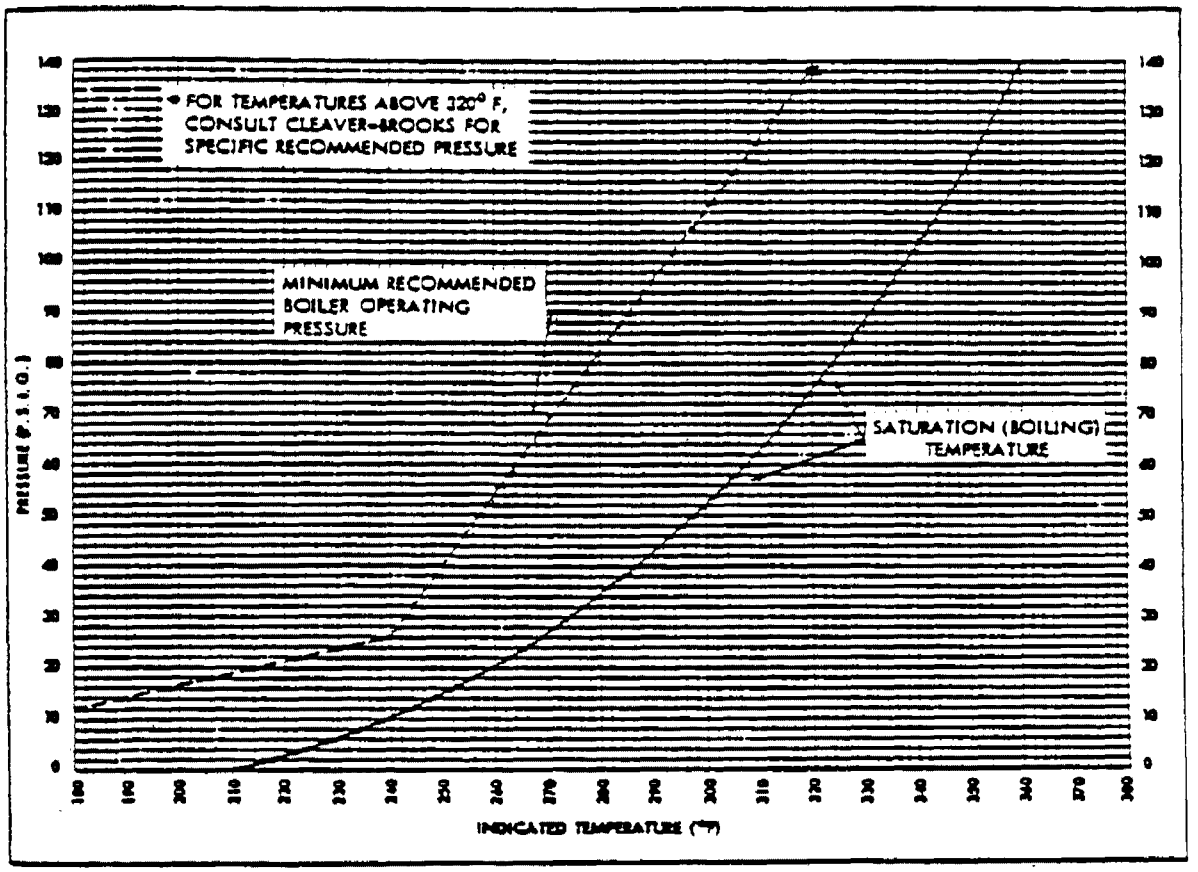
Pump Operation — Pumps are normally started and stopped by manual switches. It is also desirable to interlock the pump with the burner so that the burner cannot operate unless the circulating pump is running.

Pressure
The design of the system and the usage requirements often will 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 the boiler's internal surfaces are fully wetted at all times. It is for this reason that the internal boiler pressure, as indicated on the water pressure gauge, must be held to the level shown in Fig. 2-2.

When initially firing a newly installed boiler or when bringing an existing boiler into an operating system, the boiler or boilers to be brought on line MUST be pressurized equal to the system and/or other boilers prior to opening the header valves.

It is advisable to have a thermometer installed in the return line to indicate return water temperature. With this determined and with the supply water temperature to system known, the temperature differential will be established. With knowledge of the pumping rate, the operator easily can detect any excessive load condition and take appropriate corrective action (see Fig. 2-1).

Special caution must be taken to guard against any condition, or combination of conditions, which might lead to the transfer of cold water to a hot boiler or hot water to a cold boiler. This particularly is true in the case of boilers that are operated for purposes other than supplying hot



[FIGURE 2-2 / PRESSURE-TEMPERATURE CHART FOR HOT WATER BOILERS]

water for the normal system load (as an example, boilers equipped with coils for domestic hot water).

It cannot be over-emphasized that rapid changes in temperature within the boiler can, and sometimes do, cause damage.

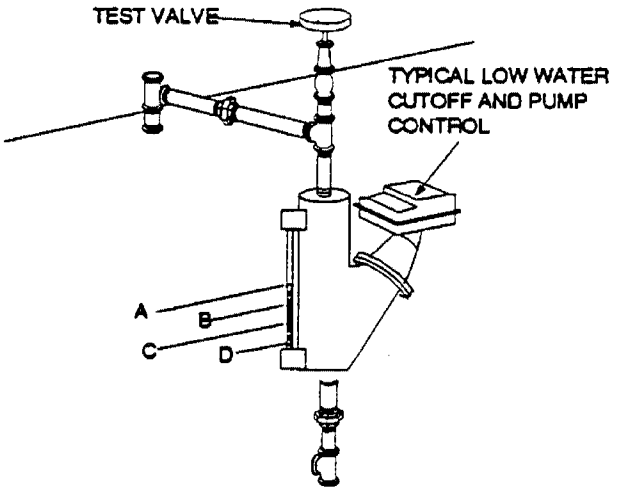
2. Steam Boiler

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 the feed pump mechanism. After opening the valves, momentarily energize the feed pump motor to establish the correct pump rotation. With the correct rotation established, close the boiler feed pump entrance switch. The pump should shut down when the boiler water level reaches the proper level shown in Fig. 2-3.

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

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



A. High level of water: Feed pump turns off at this point. Fill pressure vessel initially to this height.

B. Pump turns on when water level reaches B. Distances A-B is approximately 3/4 inch.

C. Low Water Cutoff Point: Burner will shut off if water level lowers to this point.

D. First visible point of gauge glass.

[FIGURE 2-3 / BOILER WATER LEVEL DETAILS (STEAM BOILER)]

Water Feeder Operation

This type of operation is usually applicable to boilers operating at 15 psi steam or less. It is only necessary to open the water supply line valve and the water feeder discharge valve. The water feeder should close when the water reaches the proper level as shown in Fig. 2-3.

NOTE: In the event that water column isolation valves are provided or installed, it must be established that these valves are not only open but that they are sealed or locked in the open position. If these valves are installed, it is illegal to operate the boiler with closed or unsealed open valves.

!WARNING

The isolation valves and the water column piping must be locked in the open position during operation. Failure to do so may result in a low water condition, catastrophic failure, serious personal injury or death.

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. Contact your Cleaver-Brooks local representatitive for information on how to prevent the presence of unwanted solids and corrosive gases.

The objectives of water treatment in general are:

(1) Prevention of hard scale deposits or soft sludge deposits that impair the rate of heat transfer and that lead to overheated metal and costly down-time and repairs.

(2) Elimination of corrosive gases in the supply or boiler water.

(3) Prevention of intercrystalline cracking or caustic embrittlement of the boiler metal.

(4) Prevention of carryover and foaming.

The accomplishment of these objectives generally requires proper feedwater treatment before and after introduction of water into the boiler. The selection of pre-treatment processes depends upon the water source, its chemical characteristics, amount of makeup water needed, plant operating practices, etc. These treating methods include filtering, softening, de-mineralizing, deaerating, 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, contact your Cleaver-Brooks local representative 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. Even though these units generally operate on closed systems and blowdown is seldom practiced, the need remains to be alert to system water losses and 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 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. For more information, contact your local Cleaver-Brooks representative.

On a hot water system, chemical cleaning is generally necessary and the entire system should be drained after treatment. Consult your local Cleaver-Brooks representative 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 operation and functioning of control or safety devices, but might quite possibly cause unnecessary and expensive re-work, repairs and down-time.

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

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

If any unwanted conditions are observed, contact your Cleaver-Brooks local representative for recommendations.

Any sludge, mud, or sediment found will have to be flushed out. The effectiveness of the blowdown practiced on steam boilers should 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 should be removed promptly by a boil-out with an alkaline detergent solution.

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

F. BOIL-OUT OF A NEW UNIT

The internal surfaces of a newly installed boiler may have oil, grease or other protective coatings used in manufacturing. Such coatings must be removed since they lower the heat transfer rate and could cause over-heating of a tube. Before boiling out procedures may begin, the burner should be ready for firing. The operator must be familiar with the procedure outlined under burner operation.

!WARNING
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. Failure to follow these precautions could result in serious personal injury or death.

Your Cleaver-Brooks local representative will be able to recommend a cleaning or boil-out procedure. In the event such service is unavailable or is yet unscheduled, the following information may be of assistance.

There are several chemicals suitable for this purpose. Soda ash (sodium carbonate) and caustic soda (sodium hydroxide at the rate of 3 to 5 pounds each per 1,000 pounds of water, along with a small amount of laundry detergent added as a wetting agent is one combination often used.

Generator	Water — Gallons		Water — Weight	
Sizes	Normal	Flooded	Normal	Flooded
100	875	1032	7260	8570
125	825	980	6825	8130
150	995	1180	8270	9810
200	1335	1580	11070	13100
250	1371	1630	11380	13510
300	1635	1935	13550	16050
350	1870	2220	15525	18420
400	2175	2570	18070	21350

[FIG. 2-4 / WATER CAPACITY CHART]

The suggested general procedure for cleaning a boiler is:

(1) Refer to Fig. 2-4 to determine water capacity. Have sufficient cleaning material on hand to complete the job.

(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 it 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 the top boiler openings and routed to a safe point of discharge. A relief or safety valve tapping is usually used.

(4) Water relief valves and steam safety valves must be removed before adding the boil-out solution so that neither it nor the grease that it may carry will contaminate these valves. Use care in removing and re-installing valves.

Refer to Section M in Chapter 7 for valve installation instructions.

(5) All valves in the piping leading to or from the system must be closed to prevent the cleaning solution from getting into the system.

(6) Fill the pressure vessel with clean water until all tubes are covered. Add the cleaning solution and then fill to the top. The temperature of the water used in this initial fill should be at ambient temperature.

(7) The boiler should then be fired intermittently at a low rate sufficient to hold the solution just at the boiling point. Boil the water for at least five hours. Do not produce steam pressure.

(8) Allow a small amount of fresh water to enter the boiler to create a slight overflow that will carry off surface impurities.

(9) Continue to boil and overflow until the water clears. Shut the burner down.

(10) Let the boiler cool to 120°F or less.

!WARNING
Be sure to drain the hot water to a safe point of discharge to avoid scalding or other serious personal injury or death.

(11) Remove the hand hole plates and wash the waterside surfaces thoroughly using a high pressure water stream.

(12) Inspect the waterside surfaces. If they are not clean, repeat the boilout.

(13) After closing the openings and reinstalling the safety or relief valves, fill the boiler and fire until water is heated to at least 180°F to drive off any dissolved gases that might otherwise corrode the metal.

The above procedure may be omitted in the case of a unit 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 than an accumulation of unwanted materials or corrosion does not occur.

On a hot water system, chemical cleaning is generally necessary and the entire system should be drained after treatment. Consult your Cleaver-Brooks local representative for recommendations, cleaning compounds, and application procedures.

G. WASHING OUT

1. Hot Water Boiler

In theory, a hot water system and boiler that have been initially cleaned, filled with raw water (and that water treated), 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 the operator is absolutely certain that the system is tight, then an annual waterside inspection may be sufficient.

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

2. Steam Boiler

No later than three months after initially placing the boiler into operation and starting service, and thereafter as conditions warrant, the pressure vessel should be drained after being properly cooled to near ambient temperature, handhole covers removed, and waterside surfaces inspected for corrosion, pitting, or formation of deposits.

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 flushing, this may require immediate consultation with your Cleaver-Brooks local representative 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 the frequency of pressure vessel washouts. Contact your Cleaver-Brooks local representative for more information.

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 of solids in the boiler water occurs.

Solids are brought in by the feedwater even though this water is treated prior to use through external processes that are designed to remove unwanted substances that contribute to scale and deposit formations. However, none of these are in themselves capable of removing all substances and regardless of their efficiency, some solids will be present in the boiler feedwater.

Solids become less soluble in the high temperature of the boiler water and tend to accumulate on heating surfaces. Blowdown and 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, silica and oil. Any calcium and magnesium salts in the boiler water generally are 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.

Manual Blowdown

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

The blowdown tappings are located at the bottom or lowest part of the boiler so that in addition to lowering the concentration of dissolved solids in the pressure vessel water, it also removes a portion of the sludge which accumulates in the lower part of the vessel.

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.

Continuous Blowdown

Continuous blowdown is used in conjunction with a surface blow-off tapping (furnished on units 60" diameter and larger) and is the continuous removal of concentrated water.

The surface blow-off opening, when furnished, is on the top center line of the pressure vessel and is provided with an internal collecting pipe terminating 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 water analysis results.

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

Frequency of Manual Blowdown

When continuous blowdown is utilized, manual 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 predetermined limits, manual blowdown to lower these concentrations is required.

Generally it is recommended that a steam boiler 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 schedule can be recommended by your Cleaver-Brooks local representative.

A hot water boiler does not normally include openings for surface blowdown and bottom blowdown since blowdowns are seldom practiced. The need remains to be alert to system water losses and corresponding amount of raw water make-up. A water meter is recommended for water make-up lines.

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 the blowdown piping and the tank, if used, are in proper operating condition, the discharge vents are clear of obstruction, and that the waste is piped to a point of safe discharge.

Most blowdown 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 the make or manufacture. If seatless valves are installed, follow the manufacturer's recommendations.

If a quick opening valve and 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.

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

CAUTION!

Do not pump the lever action valve open and closed, as water hammer is apt to break the valve bodies or pipe fittings or damage to the equipment could occur.

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.

Under no circumstances should a blowdown valve be left open and the operator should never leave until the blowdown operation is completed and 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 of the boiler from service and preparation for inspection.

!WARNING
To avoid the hazard of electrical shock, which could cause serious personal injury or death, we recommend the use of a low voltage flashlight during an internal inspection. Preferably, inspectors should work in pairs.

When shutting down, the load should be reduced gradually and the pressure vessel cooled at a rate that avoids damaging the 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 that can cause expanded tubes to leak. Draining the unit too quickly may cause the baking of deposits that may be present on the heating surfaces. Some heat, however, may be desirable to dry out the interior of the boiler.

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

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

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

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

After proper cooling and draining of the 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 surface also should be thoroughly cleaned so that metal surfaces, welds, joints, tube ends, fittings and any previous repairs can be readily checked.

Be sure that system valves and valves to expansion tank (hot water), steam valves, feedwater valves, blow-off valves, all fuel valves, valves to expansion tank, and electrical switches are shut off prior to opening handholes, manhole, front or rear doors, and crawlway plug. Adequately vent the pressure vessel prior to entry.

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

J. PREPARATION FOR EXTENDED LAY-UP

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

Too many conditions exist to lay down definite rules. There are two methods of storage: wet or dry. Your Cleaver-Brooks local representative can recommend the better method depending upon circumstances in the particular installation.

Whichever method is used, common sense dictates a periodic recheck of fireside and waterside conditions during lay-up to allow variations from the above methods for special area or job-site conditions.

Swing open the boiler head at the stack end of the unit to prevent the flow of warm, moist air through the boiler tubes.

Although pollution control regulations may continue to limit the permissible sulphur content of fuel oils, care must be taken to avoid corrosion problems that sulphur can cause, especially in a boiler that is seasonally shutdown. Dormant periods, and even frequent shutdowns, expose the fireside surfaces to condensation below the dew point during cooling. This moisture and any sulphur residue can form an acid solution. Under certain conditions, and especially in areas with high humidity, the corrosive effect of the acid will be serious enough to eat through or severely damage boiler tubes or other metal heating surfaces during the time that a boiler is out of service.

This condition does not generally occur during normal firing operation since the high temperature of operation vaporizes any condensation. However, proper boiler operation must be maintained, especially with a hot water boiler, to prevent the flue gases from falling below the dew point.

At the start of lay-up, thoroughly clean the fireside by removing any soot or other products of combustion from the tubes, tube sheets and other fireside surfaces. Brushing will generally suffice. Sweep away or vacuum any accumulation. The fireside surfaces may be flushed with water. However, all moisture must be eliminated after flushing and the surface dried by blowing air or applying some form of heat. It is good practice to protect the cleaned surfaces by coating them with an anti-corrosive material to prevent rust.

To prevent condensation from forming in the control cabinet, keep the control circuit energized. For extended lay-up periods, especially where high humidity or large swings in ambient temperature occur, the control should be removed and stored in a dry atmosphere.

Dry storage is generally employed when the boiler will be out of service for some time or where freezing temperatures may exist. In this method, the boiler must be thoroughly dried because any moisture would cause corrosion. Both fireside and waterside surfaces must be cleaned of all scale, deposits, soot, etc. Steps must be taken to eliminate moisture by placing moisture-absorbing materials such as quick lime (at 2 pounds for 3 cubic feet of volume) or silica gel (at 5 pounds for 30 cubic feet of volume) on trays inside the vessel. Fireside surfaces may be coated with an anti-corrosive material or grease or tar paint. Refractories should be brushed clean and wash coated. All openings to the pressure vessel, such as manhole and handholes, should 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 should be made and absorption materials renewed.

Wet storage generally is used for a boiler held in stand-by condition or in cases where dry storage is not practical. The possibility of freezing temperatures must be considered. Care must again be taken to protect metal surfaces. Vari-

ables preclude definite recommendations. However, it is suggested that the pressure vessel be drained, thoroughly cleaned internally, and refilled to overflowing with treated water. If deaerated water is not available, the unit should be fired to boil the water for a short period of time. Additional chemicals may be suggested by your Cleaver-Brooks local representative to minimize corrosion. Internal water pressure should be maintained at greater than atmospheric pressure. Nitrogen often is used to pressurize the vessel. Fireside surfaces must be thoroughly cleaned and the refractory should be wash coated.

CHAPTER 3

SEQUENCE OF OPERATION

A. General
B. Circuit and Interlock Controls
C. Sequence of Operation — Oil or Gas
D. Flame Loss Sequence

A. GENERAL

This chapter 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.

NOTE: 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.

In the schematic type wiring diagram provided for the boiler, the grounded (common) side of the power supply is shown as a vertical line on the right side of the diagram. All inductive components (coils, solenoids, transformers, lights, etc.) are connected to it. The hot side of the power supply is shown as a vertical line on the left side of the electrical schematic. All the inductive components are connected to it through switches or contacts that permit the component to function when required.

Abbreviations for the various electrical components are listed in Figure 3-1. The sequences outlined in this chapter employ these designations to aid in applying the text to the wiring diagram.

For an explanatory booklet on schematic wiring diagrams, request Cleaver-Brooks Bulletin C17-4095 from your Cleaver-Brooks local representative.

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

- The boiler water is up to the correct level closing the low water cut-off 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 cut-off setting.

[FIGURE 3-1/ELECTRICAL NOMENCLATURE]

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
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
AGV	Auxiliary Gas Valve
AH	Alarm Horn
ALFCO	Assured Low Fire Cutoff
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)
ASBR	Auxiliary Switch Bypass Relay
ASR	Alarm Silencing Relay
ASS	Alarm Silencing Switch
ASV	Atomizing Steam Valve
AT	Annunciator Transformer
ATS	Alarm Test Switch
AWCBDS	Auxiliary Water Column Blow Down 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
BFPM	Boiler Feed Pump Motor
BFPMF	Boiler Feed Pump Motor Fuses
BFPMCB	Boiler Feed Pump Motor Circuit Breaker
BFPMS	Boiler Feed Pump Motor Starter
BFPS	Boiler Feed Pump Switch
BHS	Boiler — Header Switch
BIOL	Boiler in Operation Light
BM	Blower Motor
BMCB	Blower Motor Circuit Breaker
BMCR	Blower Motor Control Relay
BMF	Blower Motor Fuses
BMPR	Blower Motor Power Relay

MNEMONIC	DESCRIPTION
	B (Cont'd)
BMPS	Blower Manual Purge Switch
BMS	Blower Motor Starter
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
CFHL	Call For Heat Light
CIPL	Changeover In Progress Light
CL	Canopy Light
CLS	Canopy Light Switch
COPS	Changeover Pressure Switch
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
CWPS	Circulating Water Pump Switch
CWSV	Cooling Water Solenoid Valve
	D
D	Denotes Digester Gas Equipment (Prefix)
DCVM	Direct Current Volt Meter
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

MNEMONIC	DESCRIPTION
	E
EDS	Emergency Door Switch
ESS	Emergency Stop Switch
ETM	Elapsed Time Meter
	F
FADI	Fresh Air Damper Interlock
FADM	Fresh Air Damper Motor
FADR	Fresh Air Damper Relay
FCIPL	Fuel Changeover In Progress Light
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
FMS	Firing Mode Switch
FORS	First Out Reset Switch
FPM	Feed Pump Motor
FPMS	Feed Pump Motor Starter
FRI	Firing Rate Interface
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
FWVAS	Feed Water Valve Auxiliary Switch
FWVT	Feed Water Valve Transformer
	G
G	Green (Color of Pilot Light)
GCAS	Gas Cock Auxiliary Switch
GCS	Gas Cock Switch
GGL	Gauge Glass Light
GOL	Gas Operation Light
GOR	Gas — Oil Relay
GOS	Gas — Oil Switch
GPS	Gas Pressure Sensor
GPV	Gas Pilot Valve
GPVV	Gas Pilot Vent Valve
GSSV	Gas Sensor Solenoid Valve
GVEL	Gas Valve Energized Light
GVTS	Gas Valve Test Switch
	H
HATC	High Ambient Temperature Control
HBWTL	High Boiler Water Temperature Light
HFAV	High Fire Air Valve
HFGV	High Fire Gas Valve
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
	H (Cont'd)
HGPS	High Gas Pressure Switch
H/LWA	High Low Water Alarm
HL	Heater Light
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.)	Instantaneous Closed
(I.O.)	Instantaneous Open
IL	Ignition Light
IM	Ignition Module
INT	Interval (Timer)
IT	Ignition Transformer
	J
JPP	Jackshaft Position Potentiometer
	L
LAMPS	Low Atomizing Media Pressure Switch
LASPS	Low Atomizing Steam Pressure Switch
LCR	Limit Circuit Relay
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

MNEMONIC	DESCRIPTION
	L (Cont'd)
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
LIAPS	Low Instrument Air Pressure Switch
LLPC	Low Limit Pressure Control
LLPR	Low Limit Pressure 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
LSPC	Low Steam Pressure Control
LSPL	Low Steam Pressure Light
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	Microammeter
MC	Modulating Control
MCS	Manual Control Switch
MDM	Modulating Damper Motor
MDMAS	Modulating Damper Motor Auxiliary Switch
MFC	Manual Flame Control (Potentiometer)
MFVL	Main Fuel Valve Light
MFWV	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

MNEMONIC	DESCRIPTION
	M (Cont'd)
(MR)	Manual Reset
MTC	Modulating Temperature Control
MVA	Make-Up Valve Actuator
	N
N	Denotes Natural Gas Equipment (Prefix)
(N.C.)	Normally Closed
(N.O.)	Normally Opened
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
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 Pilot Supply Pump Motor
OPV	Oil Purge Valve
ORV	Oil Return Valve
OSOV	Oil Shutoff Valve
OSS	Oil Selector Switch
OT	Outdoor Thermostat
OTS	Oil Temperature Sensor
OV	Oil Valve
OVAS	Oil Valve Auxiliary Switch
OVEL	Oil Valve Energized Light

MNEMONIC	DESCRIPTION
	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
PFPS	Positive Furnace Pressure Switch
PHGPS	Pilot High Gas Pressure Switch
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	Post Purge Light
PPR	Post Purge Relay
PPTD	Post Purge Time Delay
PR	Program Relay
PRL	Purge Ready Light
PS	Power Supply
PSF	Power Supply Fuse
PSS	Pump Selector Switch
PSV	Purge Solenoid Valve
PT	Purge Timer
PTS	Pump Transfer Switch
	R
R	Red (Color of Pilot Light)
RAR	Remote Alarm Relay
RATD	Remote Alarm Time Delay
RES	Resistor
RS	Range Switch
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

MNEMONIC	DESCRIPTION
	S (Cont'd)
SS	Selector Switch
SSC	Sequencing Step Controller
SSL	Safety Shutdown Light
SSR	Solid State Relay
STHWC	Surge Tank High Water Control
STHWL	Surge Tank High Water Light
STHWR	Surge Tank High Water Relay
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
TD	Time Delay
TDAS	Time Delay Auxiliary Switch
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
VM	Volt Meter
	W
W	White (Color of Pilot Light)
WC	Water Column
WCBDS	Water Column Blow Down Switch
WFNL	Water Flow Normal Light
WLC	Water Level Control
WO	Denotes Waste Oil Equipment (Prefix)
WTS	Water Temperature Sensor

- All applicable limits are correct for the burner operation.
- The load demand light glows.

All entrance switches are closed and the power is present at the line terminals of:

—Blower motor starter

—Air compressor motor starter (if provided)

—Oil heater relay (if provided)

—Oil pump motor starter (if provided)

These 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 4 and 5 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 volt, single phase, 60 Hz, alternating current.

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 these 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 these circuits are listed below and referred to in the following sequence of operation.

Limit Circuit:

- Burner switch (BS)
- Operating limit control (OLC) — pressure or temperature
- High limit control (HLC) — pressure or temperature
- Low water cut-off (LWCO)
- Gas-oil selector switch (GOS) — (Combination burner only)
- Oil drawer switch (ODS) — Oil burner
- Low oil temperature switch (LOTS) — (No. 5 and 6 oil only)
- Low gas pressure switch (LGPS)
- High gas pressure switch (HGPS)
- Fuel Valve Interlock Circuit
- Main gas valve auxiliary switch (MGVAS)
- Oil valve auxiliary switch (OVAS)

Blower Motor Start Circuit

- Blower motor starter (BMS)
- Air compressor motor starter (ACMS) (if provided)
- Air purge valve (APV) (No. 5 or 6 oil only)

Running Interlock Circuit

- Blower motor starter interlock (BMSI)
- Combustion air proving switch (CAPS)
- Atomizing air proving switch (AAPS) (if provided)

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 (F.M.), Industrial Risk Insurers (I.R.I.) or others, additional interlock devices may be used in addition to those mentioned above.

High Fire Proving Circuit

- High fire switch (HFS)

Running Interlock and Limit Circuit

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

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. When firing oil, the air compressor motor starter (ACMS) (if provided) is also powered. The air purge valve (APV) (No. 5 and 6 oil only) remains de-energized.

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. This 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 this 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 these 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.

NOTE: 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 the flame is sensed at this time.

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

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

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.

NOTE: 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 the time interval allowed for proving main flame ignition. Refer to the boiler wiring diagram.

With a proven pilot, the main fuel valve(s) (OV or MGV) 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, and 15 seconds for heavy oil. At the end of the proving period, if the flame detector still detects main flame, the ignition transformer and pilot valve are de-energized and the 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 lockout the control. Refer to flame loss sequence section for description of action.

!WARNING
The cause for loss of flame or any other unusual condition should be investigated and corrected before attempting to restart. Failure to do so may result in serious personal injury or death.

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 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 the fuel valve(s) 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 switch in the manual-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. This subjects the pressure vessel metal and refractory to undesirable conditions. The effectiveness of nozzle purging is lost on a No. 6 oil fired burner.

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

Burner Shut-Down 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 de-energized 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.

On a No. 6 oil fired burner, the air purge valve (APV) is powered from the blower motor start circuit via the contacts of the air purge relay (APR) to provide an air purge of the oil nozzle. The damper motor returns to the low fire position if it is not already in that position.

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

The program relay now is in readiness for subsequent recycling and, when steam pressure or water temperature drops sufficiently 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 a flame or a flame simulating condition occurs during the pre-purge period.

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

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 in order to avoid damage to the equipment.

(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 de-energized 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 de-energized. 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 de-energize 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.

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

The blower motor will be de-energized. 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 de-energize 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 de-energized. 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.

Most program relays have 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 in the event it is necessary. 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 that this is a safety device and for the most part it 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 to see that a safety lockout will occur under conditions of failure to ignite either pilot of main flame or from loss of flame is recommended.

CHAPTER 4

STARTING AND OPERATING INSTRUCTIONS

NOTE: If your boiler is equipped with a CB-HAWK™ boiler management control system, refer to CB-HAWK Installation, Operating, and Servicing Manual No. 750-133 for specific information regarding procedures described in this section.

A. GENERAL PREPARATION FOR START-UP — ALL FUELS

Instructions in this chapter assume that installation is complete and that all electrical, fuel, water and vent stack connections have been 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 call-out photographs and the contents of Chapter 1. Adjustment of the major components are given in Chapter 5 and this should be reviewed prior to firing. The wiring diagram should also have been studied, along with the sequence in Chapter 3.

!WARNING
It is recommended that these starting instructions be read through 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 heed this warning could result in serious personal injury or death.

Verify the supply of fuel and the 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. Make sure that treated feedwater is available and used. In heating applications, the entire system should be filled and vented. Refer to Chapter 2 for water requirements. On a steam boiler, open the test valve (Fig. 1-1) to vent air displaced during filling. Leave the test valve open until the escape of steam is noted after the burner is operating.

CAUTION!

Prior to firing a boiler, make sure that the discharge piping from the safety valves or the relief valves, and the discharge piping from all the blowdown and drain valves are piped to a SAFE point of discharge, so that emission of hot water or steam cannot possibly cause serious personal injury or death to personnel or damage to property.

Check all linkage for full and free movement of the damper and metering valves and cams. This 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 when viewed from the front of the boiler. Air pump rotation is clockwise when viewed from its drive end.

Before operating the boiler feed pump or oil supply pump, be sure all the valves in the line are open or properly positioned.

For safety's sake, make a final pre-start-up inspection, especially checking for any loose or incomplete piping or wiring or any other situations that might present a hazard.

CAUTION!

Note that the pressure vessel support legs are welded to mounting skids in front and secured by bolts at the rear of the pressure vessel. These bolts are tightened for shipment. When the boiler is installed, and prior to initial firing, the bolts securing the rear legs to the skid must be loosened to allow for expansion and contraction caused by differences in temperature between pressure vessel and skids and avoid damage to the equipment.

B. CONTROL SETTINGS - STEAM AND HOT WATER

See Chapter 5 for adjustment instructions for the following controls.

Inspect operating limit control for proper setting.

(1) 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.

(2) The temperature control on a hot water boiler should be set slightly above the highest desired water temperature but within the limits of the pressure vessel.

Inspect the high limit control for the proper setting.

(1) On a high pressure steam boiler, this control should be set approximately 10 lbs. above the operating limit pressure control setting, if feasible, or midway between the operating limit pressure and safety valve setting. The setting on a low pressure steam boiler may be 2 or 3 lbs. above the operating limit setting, but must not exceed the safety valve setting.

(2) On a hot water boiler, the high limit temperature control should be 5-10° above the operating limit temperature control setting, but within the limits of the design pressure of the pressure vessel.

Inspect the modulating control for proper setting. This control must be set and adjusted so that the modulating motor returns to low fire position before the operating limit control opens. It is further desirable to have its low point setting somewhat below the cut-in setting of the limit control so that burner operates in low fire position for a brief period on each start rather than immediately driving to a high fire position.

NOTE: The settings of all the above controls may require some readjustment after the boiler is started and running for a short period. The scale settings on the controls are relatively accurate, but principally are for use as guides. Final adjustment should be based on and agree with the reading of the steam pressure gauge or the water temperature thermometer.

Inspect the low water cut-off and pump control as well as the auxiliary low water cut-off (if equipped with this optional device). Normally, no adjustment is required since these controls are pre-set by the original manufacturer. Check for freedom of float movement. Float movement can be verified by observing the level of water in the gauge glass when the water supply has been cut off either by the stopping of the feed pump or by the closing of a valve, and the restarting of the pump or opening of the valve when water is drained from the pressure vessel. The importance of proper functioning of low water controls cannot be over-emphasized. Make sure that the control and the piping are level.

The settings of controls relating to fuel, either oil or gas, are covered in subsequent sections.

In the event the boiler is equipped with optional control devices not listed here, be certain to ascertain that their settings are correct. If additional information if required, see your Cleaver-Brooks local representative or contact Cleaver-Brooks.

On initial start-up or whenever the boiler is placed into operation from a "cold" start, the manual-automatic selector switch should be set at "manual" and the manual flame control set at "close." After the boiler is in operation and thoroughly warmed, the selector switch should be turned to "automatic," so that the burner firing rate may be controlled by the modulating control in accordance with load demands.

Close all power entrance switches (supplied by others).

C. GAS PILOT

The gas pilot should be checked for satisfactory performance prior to initial firing. Follow the pilot flame adjustment instructions given in Chapter 5.

On initial starting attempts, several efforts might be required to accomplish bleeding time of pilot line. While checking the pilot adjustment, observe whether the pilot flame is extinguished promptly when the burner switch is opened. A lingering flame is indicative of a leaking gas pilot valve and a condition requiring correction before proceeding.

D. ATOMIZING AIR

The supply and pressure of the atomizing air on an oil fired burner should be checked. Before starting, inspect the oil pump lube oil level. Add oil if necessary to bring the level to the mid-point or slightly higher of the sight glass. Use SAE 20 detergent oil of a grade mentioned in Chapter 7 and fill in accordance with the instructions given there.

Check the oil level of the air intake strainer.

To verify air flow and pressure, place the run/test switch on the program relay to the test position. If this is a combination fuel burner, make sure that the gas/oil selector switch is set to "oil." Turn the burner switch on. The burner will cycle to the low fire pre-purge position and stop there.

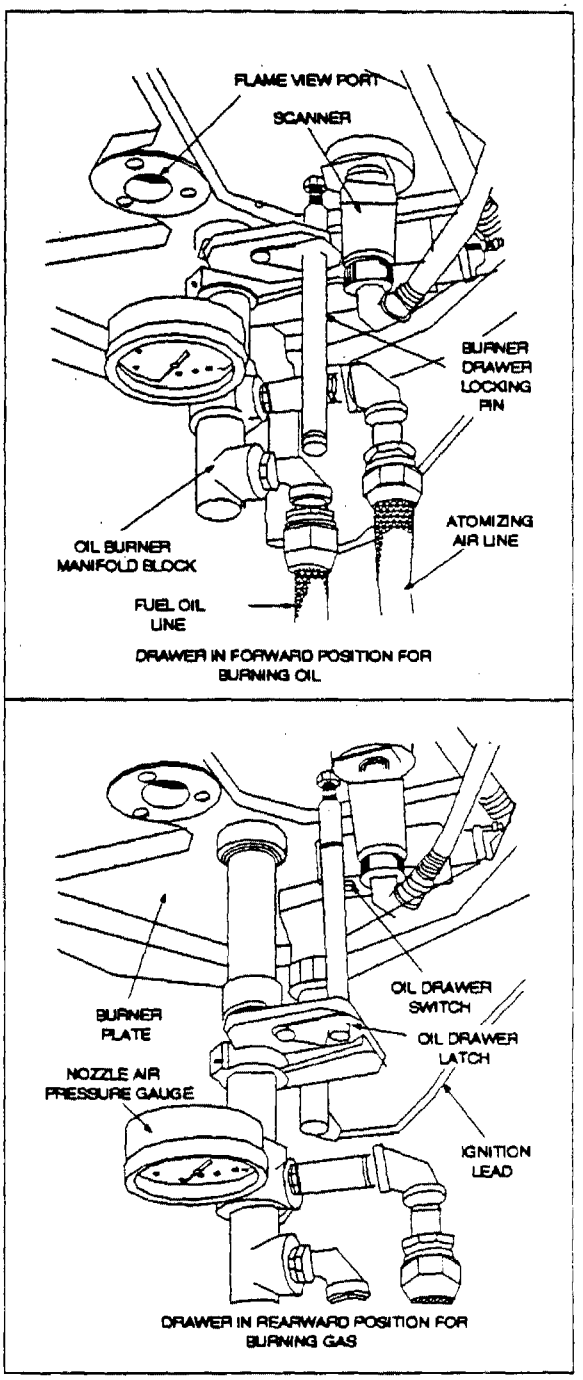
Observe the reading on the air pressure gauge (Fig. 4-1). With no oil flow, the pressure should be a minimum of 7 psi.

If there is no pressure, determine the cause and correct it before proceeding. Check for obstructions in the air inlet line, incorrect rotation (air pump rotation is clockwise), or a loose oil nozzle or other leaks. If the pressure is much higher without any oil flow, check for an obstruction in the discharge line or at the oil nozzle.

The air pressure will increase when an oil flow exists. At low firing rate, the air pressure may rise to 12 psi or more.

CAUTION!

The air pressure should not exceed 30 psi at high fire. Greater air pressure causes excessive wear of the air pump, increases lube oil usage, and can overload the motor, thus causing damage to the equipment.



[FIGURE 4-1 / POSITIONS OF BURNER DRAWER FOR OIL AND GAS]

NOTE: Abnormally high pressure indicated on the nozzle air pressure gauge is an indication that the burner nozzle has become clogged. In this event, check the nozzle and clean as necessary.

After the air flow has been verified, turn the burner switch off and return the run/test switch to the run position.

E. FIRING PREPARATIONS FOR NO. 2 OIL (SERIES 100-200)

Prior to initial firing, oil flow and pressure should be established and verified. Atomizing air pressure should also be established as outlined in Section D. The schematic flow diagram (Fig. 1-11) indicates the flow of fuel and atomizing air.

If the burner is a combination fuel model, make certain that the main gas shut-off cock is closed and set the gas/oil selector switch to "oil." Insert the burner drawer gun into its most forward position and latch it in place (see Fig. 4-1).

Oil Flow — Open all valves in the oil suction and oil return lines.

If the oil supply tank is located above the level of the pump and flow to the pump is by gravity, then it usually will be necessary to vent the suction line to allow oil to fill the line. This generally can be accomplished by cracking a union fitting, or by opening the cap of the oil strainer using care to prevent spillage of oil. Tighten fitting or cap as soon as oil flow appears.

If the oil supply tank is below the level of oil pump, it is **MANDATORY** that the suction line to the pump must be completely filled with oil prior to starting the pump to avoid the possibility of damage to the pump gears through operation without the lubrication afforded by the fuel oil. Non-lubricating fluids such as kerosene should not be used for priming.

Prior to priming the suction line and the initial start, check to make certain that all plugs, connections, etc., have been securely tightened to prevent leaks.

If the fuel oil supply originates from a pressurized loop, it is assumed that the pressure of the loop will be at a minimum of 75 psi. Boilers would not then have individual pumps furnished as standard equipment. Under these conditions, the relief valve at the terminal block should be adjusted to the point where it becomes inoperative.

A standard equipped boiler has a selector switch incorporated in the oil pump motor starter. Momentarily energize the starter to check for proper pump rotation. With the rotation verified, operate the pump to determine that oil circulation exists. Observe the oil burner pressure gauge for indication that flow is established. If no pressure shows on this gauge after a few moments, stop the oil pump and re-prime. If the supply tank is lower than the pump, it is possible that the initial priming of the suction line, followed by operation of the pump, will not establish oil flow. This might be caused by obstruction in the suction line, excessive lift, inadequate priming, suction line leaks, etc. If the oil flow is not readily established, avoid prolonged operation of the pump to minimize risk of damage to internal parts of the pump. If the oil flow is not established after a second or third priming attempt, a full investigation is required to determine the cause.

A vacuum (or a compound pressure-vacuum) gauge should be installed at the suction port of the pump and its reading observed and recorded for future guidance. If a vacuum condition exists, this reading will reveal the tightness of the system. It is advisable to maintain the vacuum reading at less than 10" W.C. A vacuum in excess of this may allow oil to vaporize causing cavitation, loss of prime, and an unstable firing condition.

Oil Pressure — Oil supply pressure is regulated by adjusting the pressure relief valve at the oil terminal block (Fig. 1-1). A pressure gauge should be installed in the terminal block and the relief valve adjusted to obtain a minimum reading of 75 psi when the burner is firing at maximum rate.

When oil is supplied from a pressurized loop to a multiple boiler installation, the relief valve in the loop should be properly adjusted to provide this reading. In this circumstance, the relief valve at the terminal block should be adjusted to the point where it will be inoperative (or removed and openings plugged). To render the valve inoperative, turn the adjusting screw in as far as possible.

Adjustment may also be required to the regulator on the fuel oil controller (Fig. 1-5). This pressure regulating valve is equipped with tubing that directs and adds atomizing air pressure to the adjustable spring pressure. Since the atomizing air pump is not running at this time, only tentative adjustment can be made. Without this air supply, adjust the fuel oil pressure regulator so that the oil burner gauge registers approximately 35 psi.

The pressure will be higher when the flame is present, and will increase as the firing rate increases. After the burner is firing and when the air pump is running, final adjustment can be made at the fuel oil controller.

Final regulation of the oil flow to the nozzle can be done later, if necessary, by adjusting the metering cam screws as outlined in Chapter 5.

Suggested oil pressures at high fire operation:

Oil Supply at the
Fuel Oil Controller . . .75 psi

Oil Burner
Pressure Guage . . . . .30-45 psi

Starting — When all the conditions covered above and in Sections A, B, C and D are assured, the burner is ready for firing. Refer to Section H of this chapter for further starting and operating information.

F. FIRING PREPARATION FOR NO. 6 OIL (SERIES 400-600)

Prior to initial firing, the oil flow, pressure, and temperature should be established and verified. The atomizing air pressure should also be established as outlined in Section D. The schematic flow diagram (Fig.1-12) indicates the flow of fuel and atomizing air.

If the boiler is a combination fuel model, make certain that the main gas shut-off cock is closed and set the gas/oil selector switch to "oil." Insert the burner drawer gun into its most forward position and latch it in place (see Fig. 4-1).

Oil Flow — Open all valves in the oil suction and oil return lines. Open the by-pass valve on the fuel oil controller (Fig. 1-6) until the oil flow is established. Normally, the orifice valve is left in a closed position. However, on cold starts, it may be opened for brief periods to aid in establishing oil flow. The by-pass and orifice valves must be returned to a closed position as soon as proper oil flow is established as indicated by a reading on the oil supply pressure gauge (Figs. 1-2 and 1-8). Do not attempt to set pressures while these valves are open.

Momentarily energize the fuel oil pump starter to check for proper pump rotation. With the rotation verified, prime the suction line strainer with oil and start the fuel oil pump by closing its power entrance switch. Observe the oil supply pressure gauge for indication that oil flow is established. If no pressure shows on gauge after a few moments, stop the oil pump and re-prime. Heavy oil in the storage tank must be at a temperature to provide oil viscosity to permit flow through the oil pump and suction line. If oil flow is not

established after several attemps, the conditions preventing oil flow must be determined and corrected to avoid damage to the pump's internal mechanism.

A vacuum (or compound pressure-vacuum) gauge should be installed in the oil suction line and its reading observed and recorded for future guidance. This gauge reveals the tightness of the system.

Oil Pressure — Oil pressure is regulated at several points. The first is at the oil heater relief valve (Figs. 1-2 and 1-8). This should be set so that at maximum firing rate a minimum reading of 75 psi is obtained on the oil supply pressure gauge.

The other pressure adjustments are made at the regulators on the fuel oil controller (Fig. 1-6). Both the pressure regulating and the back pressure relief valves are equipped with tubing that directs and adds atomizing air pressure to the adjustable spring pressure. Since the air pump is not running at this time, only tentative adjustments can be made. Without this air supply, adjust the fuel oil pressure regulator so that the burner oil pressure gauge registers approximately 35 psi. Adjust the back pressure relief valve so that its gauge reads about 10 psi less than the burner gauge.

After the burner is firing, further adjustments can be made if necessary to these valves.

The pressure will be higher when a flame is present, and will increase as the firing rate increases. The pressure reading on the two gauges on the controller will, despite this fluctuation, should be adjusted to retain a nearly constant difference of 10 psi.

Final regulation of oil flow to the nozzle can be done, if necessary, by adjusting the metering cam screws as outlined in Chapter 5.

Suggested oil pressures at high fire operation:

- Oil supply at the fuel oil controller — 75 psi (minimum at maximum firing rate).
- Oil burner pressure gauge — 40-50 psi
- Oil return pressure gauge — 10 psi less than oil supply pressure.

Oil Temperature

CAUTION!

Before turning on the electric oil heater switch, make certain that the heater shell is filled with fuel oil and the flow is established in order to avoid damage to the equipment.

After determining that the heater shell is filled and that fuel oil circulation exists, turn the oil heater switch to "on." Adjust the electric oil heater thermostat (Figs. 1-2 and 1-8) to maintain an oil temperature of approximately 200°F.

The electric heater on burners equipped for No. 6 fuel oil is sized so that it is capable of supplying heated oil at a rate no greater than that required for low fire operation and is primarily supplied for convenience on cold starts. Heating coils utilizing either steam or hot water are supplied to provide sufficient heat so that higher rates of firing can be accomplished once steam pressure or hot water is available. In normal operation, the thermostat governing the electric heating element is kept at a lower setting than the thermostat governing the admission of steam or hot water circulation, so that heating is not performed electrically except when steam or hot water is not available.

Set the steam thermostat (Fig. 1-8)) or the hot water thermostat (Fig. 1-2) to maintain an oil temperature of 220-230°F. The electric heater will be turned off automatically as soon as steam or hot water provides heat.

NOTE: The temperatures listed are tentative. The composition of the fuel oil in a given grade can vary necessitating a higher or lower preheating temperature. The viscosity of the oil at the nozzle should be less than 300 SSU and preferably less than 150 SSU. The actual temperature of the oil at the burner should be determined by flame appearance and good combustion based on a stack analysis. See Chapter 5 for additional information.

Close the manual by-pass valve after temperature rise on the fuel oil controller thermometer is noted. Make certain that hot oil is moving through the controller. The orifice gate valve must also be closed. If temperature drops, open the orifice gate valve until a rise is noted, then close it.

Once the correct setting of the heater thermostats has been established, set the low oil temperature switch (Figs. 1-2 and 1-8) at a point approximately 30° lower than the normal operating temperature. If the system is equipped with a high oil temperature switch, this should be set to open at 20°-30° higher than normal operating temperature.

Starting — When all the conditions covered above and in Sections A, B, C and D are assured, the burner is ready for firing. Refer to Section H of this chapter for further starting and operating information.

G. FIRING PREPARATIONS FOR GAS (SERIES 200-400-700)

Prior to initial starting, check the linkage attached to the gas butterfly valve to see that movement is free from binding.

Verify the presence and availability of gas. On a new installation, representatives of the gas utility should be present when gas first flows into the system to supervise purging of the new gas line unless they already have done so.

Determine that the pilot is operating properly as outlined in Section C of this chapter.

Determine that sufficient pressure exists at the entrance to the gas train. This can be done by installing a test gauge downstream of the regulator.

The gas pressure regulator must be adjusted to the proper pressure level. Since this regulator is generally supplied by others, adjustment should proceed according to instructions supplied by its manufacturer.

It is necessary for the operator to know the burner requirements in gas quantity and pressure. This information can generally be found on the Dimension Diagram (DD) supplied by Cleaver-Brooks for the specific installation. Should this information not be readily available, consult the Cleaver-Brooks Service Department, giving the boiler serial number. Chapter 5 contains additional information along with standard gas flow and pressure requirements. This section should be completely reviewed prior to start-up.

If the burner is a combination fuel model, set the gas/oil switch to "gas." Withdraw the oil burner gun and latch it in its rearward position.

On initial start-up, it is recommended that the main gas shut-off cock (Fig. 1-3) remain closed until the programmer has cycled through prepurge and pilot sequences. When the fuel valve light on the control panel comes on, observe the action of the motorized gas valve stem to determine that it opens when energized. As soon as this is confirmed, turn the burner switch "off" and let the programmer finish its cycle. Check to see that the gas valve has closed. Again turn the burner "on" and when the fuel valve light glows slowly open the main gas cock. The main flame should ignite unless there is air present in the line. If the flame is not established within about 5 seconds, turn the burner switch "off" and allow

the programmer to re-cycle normally for a new lighting trial. Several efforts may be necessary to "bleed" air from the line.

!WARNING
Do not repeat unsuccessful lighting attempts without rechecking the burner and pilot adjustments. Damage to the boiler or serious personal injury or death may result.

NOTE: The burner and control system are 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 to take any action that might circumvent this feature.

Once main flame is established, observe that it is extinguished promptly when the burner is shut off. Flame may continue to burn for a second or two after normal shutdown due to the gas remaining downstream from the fuel valve. If the flame continues to burn for a longer period or during blower motor spindown, immediately turn the burner switch off and close the main gas cock. Investigate and correct the cause of the valve leakage before relighting the burner. The main gas valve is tight seating provided nothing prevents tight closure. Foreign material may be present in either new or renovated gas lines unless adequate care is taken in cleaning and purging.

When the conditions covered above and in Sections A, B and C are assured, the burner is ready for firing. Refer to Section H of this chapter for further starting and operating information.

H. START-UP, OPERATING AND SHUTDOWN – ALL FUELS

Depending upon the fuel being burned, the applicable previous sections in this chapter should be reviewed for preliminary instructions.

When firing with oil, make certain that the burner gun is in its most forward position and latched in place (see Fig. 1-4). When firing with gas, the burner gun should be properly withdrawn and latched in place. The fuel selector switch should be accordingly set to either "oil" or "gas."

Set the manual-automatic switch (Fig.1-7) to "manual" and turn the manual flame control to "close."

Turn the burner switch to "on." The load demand light should glow, and the low water level light should remain out indicating a safe water level in the boiler. The programmer will proceed through the normal operating sequence. (See Chapter 3 for sequence details.)

NOTE: 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 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.

!WARNING

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 furnance or flue passages. Failur to heed this warning could result in serious personal injury or death.

CAUTION!

The burner and control system are 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 this feature thus causing damage to the equipment.

After main flame ignition, the burner should be left on manual control at its low fire setting (that is, with manual flame control at "close") until the boiler is properly warmed. Close the steam header.

In the case of a steam boiler, CLOSE THE TEST VALVE when 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 to no higher than the third cam screw. Operate at this 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 the fuel flow regulated as required. Refer to adjustment procedures in Chapter 5. After making the high-fire adjustment, manually decrease the firing rate, stopping at each cam screw to analyze combustion gases and adjust as required.

To properly perform this testing and adjusting, it is necessary that the burner be allowed to fire at each rate sufficiently long enough to achieve a stable condition.

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 operating limit pressure or temperature is reached, unless:

(1) The burner is manually turned "off."

(2) A low water condition is detected by the low water level control.

(3) The current or fuel supply is interrupted.

(4) Combustion or atomizing air pressure drops below the minimum level.

NOTE: 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 Chapter 6.

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 de-energized and the flame extinguished. The timer begins operation as 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 de-energized. The air pump motor of an oil-fired burner is also de-energized. The timer has returned to its original starting position and stops. The unit is ready to re-start.

CAUTION!

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 preventing tight closure. This is especially true in new installations. Promptly correct any conditions causing leakage in order to avoid damage to the equipment.

I. 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 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 the 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 cutoff 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 desired operating pressure range. See Chapter 5 for instructions on the adjustment of controls.

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 5 for instructions on the adjustment of the controls.

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

Proper operation of the flame failure device should be checked at the time of startup and at least once a week thereafter. Refer to Chapter 7 for information on flame safety checks. Check the program relay's annunciation of any system failure. Observe the promptness of ignition of the pilot flame and the main flame.

Check for tight shut-off 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.

Refer to the adjustment procedures and maintenance instructions given in Chapters 5 and 7.

CHAPTER 5

ADJUSTMENT PROCEDURES

A. General
B. Linkage-Modulating Motor & Air Damper
C. Modulating Motor
D. Modulating Motor Switches —Low Fire and High Fire
E. Operating Controls General
F. Modulating Pressure Controls —(Steam)
G. Operating Limit Pressure Control —(Steam)
H. High Limit Pressure Control — (Steam)
I. Modulating Temperature Control — (Hot Water)
J. Operating Limit Temperature Control — (Hot Water)
K. High Limit Temperature Control — (Hot Water)
L. Low Water Cut-Off Devices
M. Combustion Air Proving Switch
N. Atomizing Air Proving Switch
O. Gas Pilot Flame Adjustment
P. Gas Pressure and Flow Information
Q. Gas Fuel Combustion Adjustment
R. Low Gas Pressure Switch
S. High Gas Pressure Switch
T. Fuel Oil Pressure and Temperature —General
U. Fuel Oil Combustion Adjustment
V. Burner Drawer Adjustments
W. Oil Drawer Switch
X. Low Oil Temperature Switch
Y. High Oil Temperature Switch
Z. Low Oil Pressure Switch
AA. Electric Oil Heater Thermostat
BB. Steam Oil Heater Thermostat
CC. Hot Water Oil Heater Thermostat
DD. Steam Heater Pressure Regulator

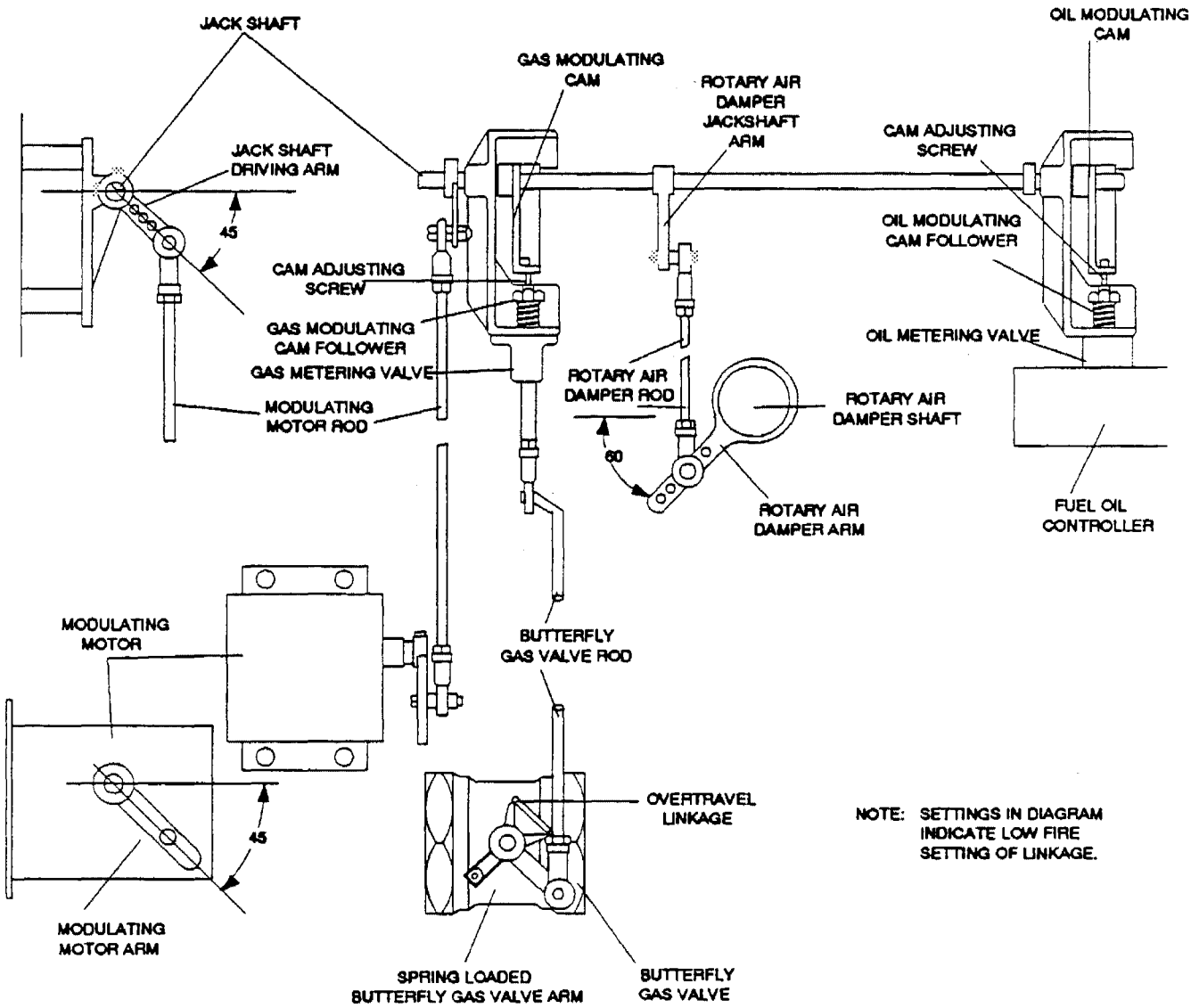
NOTE: If your boiler is equipped with a CB-HAWK™ boiler management control system, refer to CB-HAWK Installation, Operating and Servicing Manual No. 750-133 for specific information regarding procedures described in this section.

A. GENERAL

While each boiler is tested for correct operation before shipment from the factory, variable conditions such as burning characteristics of the fuel and operating load conditions may require further adjustment after installation to assure maximum operating efficiency and economy.

A combustion efficiency analysis made during the initial start-up will help to determine what additional adjustments are required in a particular installation.

Prior to placing the boiler into 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.



[FIGURE 5-1/ COMPLETE LINKAGE ASSEMBLY — COMBINATION GAS AND OIL]

The adjustment procedures in this chapter apply to standard components furnished on steam or hot water boilers fired with gas and/or the various grades of oil.

High Turndown Burner

In order to reduce burner cycling and to improve operating efficiency, burners have been designed for enhanced fuel turndown capabilities. A High Turndown Burner (HTB) is installed on 250 Hp to 800 Hp boilers equipped to fire light oil (Series 100), or gas, (Series 700), or both (Series 200). On the High Turndown Burner, air and fuel inlets, the diffuser, and the air damper control linkage are designed for higher turndown performance.

The High Turndown Burner can be identified from the natural gas housing, which is spudded, and the burner diffuser, which has a circular pattern of 5/8" holes around the front finned face.

CAUTION!

Observe that proper air damper linkage and fuel metering adjustment procedures are followed for standard (Series 400 or 600) or HTB (Series 100, 200 or 700) burners to avoid damage to the equipment. The burner series is identified on the boiler data plate affixed to the front head of the boiler.

Contact your local Cleaver-Brooks authorized Representative for recommendations covering special controls that are not included in this chapter.

B. LINKAGE-MODULATING MOTOR AND AIR DAMPER

The linkage consists of various arms, connecting rods, and swivel ball joints that transmit motion from the modulating motor to the metering cam(s), to the rotary air damper, and to the gas butterfly valve, if used.

When properly adjusted, a coordinated movement of the damper and metering cams within the limits of the modulating motor travel is attained to provide proper fuel-air ratios through the firing range.

In linkage adjustments, there are several important factors that must serve as guides.

(a) The modulating motor must be able to complete its full travel range.

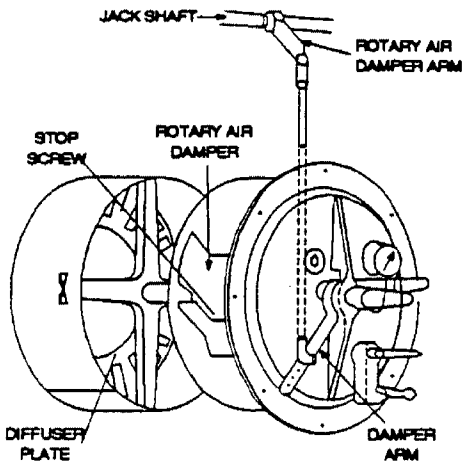
CAUTION!

Restriction of full travel will cause definite damage to this motor.

b) Initial adjustment should be made with the motor in full closed position, that is with the shaft on the power end of the motor in its most counterclockwise position.

(c) The closer the connector is to the drive shaft the less the arm will travel, while the closer the connector is to the driven shaft the farther that arm will travel.

(d) Over-travel linkage, where used, should not be required to extend its spring to fullest stretch.



[FIGURE 5-2/ ROTARY AIR DAMPER 3/4 VIEW]

With the modulating motor in the low fire position, the arm on its shaft should be at an angle of 45° below the horizontal. The driven arm on the jack shaft should be parallel to this. Secure both arms and fit the connecting linkage rod in place between them. Refer to Figure 5-1.

Position the oil and/or gas modulating cams on the jackshaft so that the cam follower assembly is between the first and second cam adjusting screws (under the first adjusting screw for a High Turndown Burner). In this position, fuel delivery is at low fire rate. Tighten the set screws to secure the cams on the jackshaft.

Refer to Figure 5-2. The stop screw in the rotary air damper limits damper travel at both closed (low fire) and fully opened (high fire) positions. This screw is provided so that it is possible to tell, even with the burner in place, whether the damper rotor is in fully opened or closed position by rotating the damper open and closed by means of the damper arm. Normally, the rate of flow of air through the damper with the rotor in low fire position is about one-third of maximum for a standard burner, or one-sixth for a HTB.

The amount of angular movement controlling the rate of air flow is determined by the location of the ends of the rotary air damper rod in both the jackshaft arm and the air damper arm. When the air damper is in the low fire position, the jackshaft arm should be at 45° (47-1/2° for HTB) and the rotary air damper arm should be at approximately 60° below horizontal (Figure 5-1). This is to ensure that the angular movement of the damper starts slowly, increasing in rate as the high fire position is approached.

Prior to initially firing a boiler, it is advisable to check for free movement of the linkage. The damper motor must be allowed to complete its full stroke and the damper must move freely from low to high fire position.

Adjustment of linkage connected to a gas butterfly valve is described in Section Q of this chapter.

C. MODULATING MOTOR

The modulating motor used in this application has a 90° shaft rotation. The motor manufacturer also provides a 160° stroke model for other applications. If a replacement is obtained from someone other than a Cleaver-Brooks Service or Parts representative, it may have an incorrect stroke. To prevent damage, determine the 90° stroke prior to installing a replacement.

This may be determined by powering the motor and connecting terminals R-B to actually determine the stroke as the motor drives to an open position.

If adjustment to the stroke is required, refer to the manufacturer's Technical Bulletin. The motor may be damaged if it is unable to complete its full stroke.

D. MODULATING MOTOR SWITCHES – LOW FIRE AND HIGH FIRE

The modulating motor contains either one or two internal switches depending upon application. These single-pole, double-throw, micro-switches are actuated by adjustable cams attached to the motor shaft.

Factory replacement motors have the cams preset. The low fire start switch is set to make the red and yellow leads at approximately 8° on the motor closing. The high fire purge air proving switch (M954B motor) is set to make red and blue tracer leads at approximately 60° on motor opening. Normally these settings are left as is but job conditions may require readjustment.

If the cams require adjustment or resetting, follow the instructions in the manufacturer's Technical Manual.

E. BURNER OPERATING CONTROLS – GENERAL

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 and that connecting tubing is not kinked.

Controls are carefully calibrated during their manufacture and normally do not require recalibration. The dial settings generally are 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 readjust the control setting to agree with these readings. This is predicated, however, on pressure gauges and thermometers being accurate.

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

(a) The burner will operate in low fire position prior to shut down.

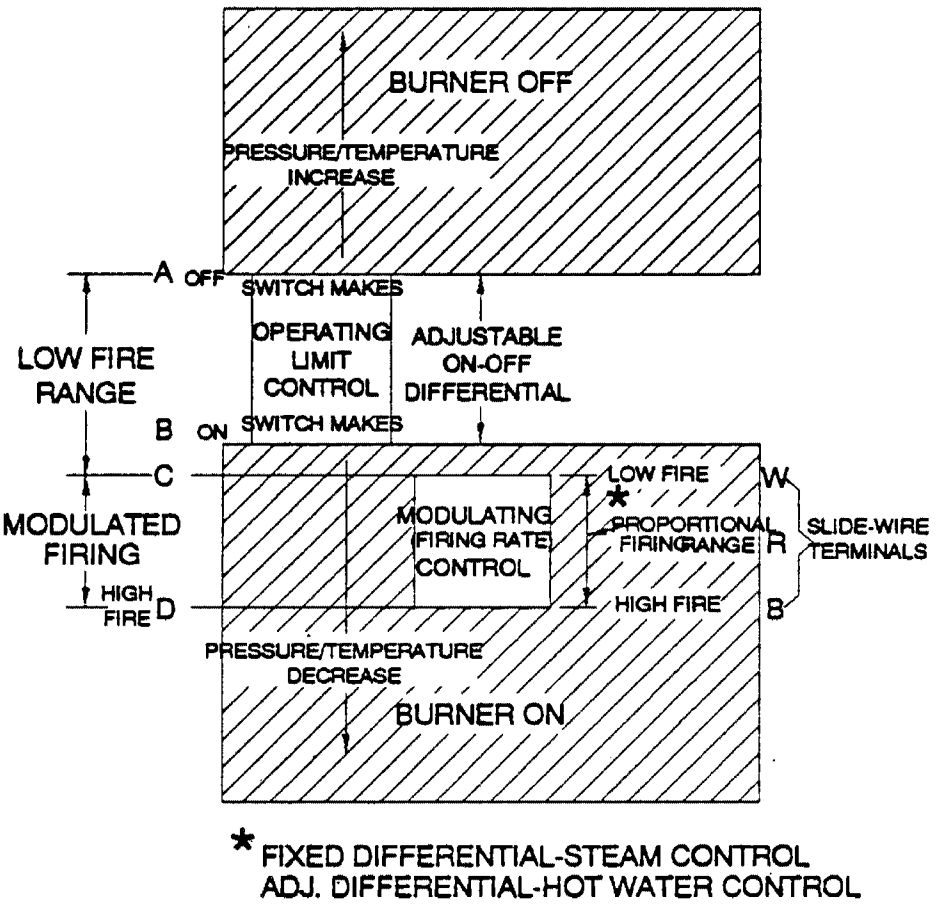
(b) The burner will operate at low fire for a brief period on each start during normal operation.

(c) Frequent burner on-off cycling will be avoided.

Figure 5-3 depicts a typical relationship of the setting of the operating limit control and the modulating control. Please note that this is not drawn to any scale. The burner will be "on" whenever the pressure or temperature is below point B and "off" whenever pressure or temperature is above point A. The distance between points A and B represents the "on-off" differential of the operating limit control.

In normal operation, the burner will shut down whenever the pressure or temperature reaches setting A. The switch in the operating limit control will open. As the pressure or temperature drops back to B, the switch closes and the burner will restart. The modulating control will be calling for the modulating motor to be in low fire position at this point. If the load exceeds this low fire input, the modulating control will respond to increase the firing rate proportionately as pressure or temperature falls toward the point D. The modulating motor will stop at any intermediate point between C and D whenever the fuel input balances the load requirement. As the load requirement changes, the firing rate will change accordingly. This is referred to as modulated firing.

Point D represents the maximum firing rate of the burner. In the event pressure or temperature drops while the burner is firing at its maximum input, this is indicative that the load exceeds the generating rate of the boiler.



[FIGURE 5-3 / OPERATING CONTROL AND MODULATING CONTROL ACTIONS]

Although a gap is shown between B and C, these points may well coincide if required by load conditions. When set as shown, the burner will be in a low fire position upon a restart and will fire at that rate for a short period of time before falling pressure or temperature requires an increase in the firing rate. From this illustration it can be seen that this desirable objective will not be attained if setting C overlaps point B. In that event, upon a restart, the burner would drive to a higher firing position immediately after the main flame was proven, and the brief period of low heat input would not occur. Actual settings will, of course, depend greatly upon load conditions, which will affect the amount of differential permitted to the operating limit control and to the gap, if any, between B and C.

CAUTION!

Setting operating controls in such a way that the burner drives to a higher firing position immediately upon restart can create cycle stress to the pressure vessel and eventual pressure vessel failure.

When firing a cold boiler, the burner must be kept under manual flame control until normal operating pressure or temperature is approached. The size of the flame may be manually increased to gradually build up pressure or temperature. If the burner is not under manual control on a cold start, it immediately will move to high fire as soon as the program control releases the circuit that holds

the burner in low fire during ignition. The modulating control will be calling for higher input and the burner will move to that position as rapidly as the damper motor can complete its travel. This rapid heat input can subject the pressure vessel metal and refractory to undesirable conditions.

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 system 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 as shown in Fig. 2.2.

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 for maximum utilization of the modulating firing system.

To accomplish this, and assuming that air/fuel combustion ratios have been set, make approximate adjustments to the controls to bring the boiler pressure or temperature to meet the load requirements.

To properly set the modulating control, carefully adjust it under load conditions, until the load is maintained with the burner firing at a steady rate. The firing rate at that point may be full high fire or slightly less, depending upon the relationship of the boiler size to the load.

When the modulating control is set in this manner and if the burner is at full high fire, the scale setting of the modulating pressure control on a steam boiler will have a reading that indicates the low point of the modulating range. This fixed differential range is described later in this section. The scale setting of the modulating temperature control on a hot water boiler will have a reading that indicates the midpoint of the modulating range. This also is described later.

The operating limit control now should be adjusted and its differential established. See directions later in this section for the mechanics of adjusting. In an installation that does not require a very close control of steam pressure or water temperature this adjustable differential should be set as widely as conditions permit, since this will provide less frequent burner cycling.

The high limit control provides a safety factor to shut the burner off in the event the operating limit control should fail to do so. The setting of this control should be sufficiently above the operating limit control to avoid nuisance shutdowns. The setting, however, must be within the limits of the safety valve settings and preferably not exceed 90 percent of the valve setting. This control requires manual resetting after tripping.

In the setting of these controls, consideration must be given to the time required for a burner restart. Upon each start, there is a prepurge period of some length, plus the fixed time required for the proving of the pilot and main flame. This, plus approximately 1/2 minute 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:

F. MODULATING PRESSURE CONTROL (Steam)

Turn the adjusting screw until the indicator is opposite the low point of the desired modulating range. Modulated firing will range between this point and a higher point equal to the modulating range of the particular control. In 0-15 psi controls the range is 1/2 lb.; in 5-150 psi controls the range is 5 lbs.; in 10-300 psi controls the range is 12 lbs.

CAUTION!

To prevent burner shutdown at other than low fire setting, adjust the modulating pressure control to modulate to low fire BEFORE the operating limit pressure control shuts off the burner. Failure to heed this caution could result in damage to the equipment.

G. OPERATING LIMIT PRESSURE CONTROL (Steam)

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.

H. HIGH LIMIT PRESSURE CONTROL (Steam)

Set "cut-out" (burner off) pressure on the scale using the adjusting screw. The control will break a circuit 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 the safety valve setting. This control requires manual resetting after tripping on a pressure increase. To reset, allow pressure to return to normal and then press the reset button.

I. MODULATING TEMPERATURE CONTROL (Hot Water)

Turn the knob on front of the case until the pointer indicates the desired setpoint temperature. This is the center point of a proportional range. The control has a 3-30° differential and may be adjusted to vary the temperature range within which modulation is desired. With the cover off, turn the adjustment wheel until the pointer indicates the desired range.

CAUTION!

To prevent burner shutdown at other than low fire setting, adjust the modulating temperature control to modulate to low fire BEFORE the operating limit temperature control shuts off the burner. Failure to heed this caution could result in damage to the equipment.

J. OPERATING LIMIT TEMPERATURE CONTROL (Hot Water)

Set the "cut-out" (burner off) temperature on the 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 adjusted from 5° to 30° F.

K. HIGH LIMIT TEMPERATURE CONTROL (Hot Water)

Set the "cut-out" (burner off) temperature on the scale using the adjusting screw. This control will break the circuit and lock out on a rise in water temperature above the setting. The setting should be sufficiently above the operating limit temperature to avoid unnecessary shutdowns. On a 30 lb. hot water boiler, the setting is not to exceed 240° 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.

L. LOW WATER CUTOFF DEVICES (Steam and Hot Water)

No adjustment is required since these controls are preset by the original manufacturer. However, if water level is not maintained as shown in Figure 2-3, inspect these devices immediately and replace as required.

M. COMBUSTION AIR PROVING SWITCH

Air pressure against the diaphragm actuates the switch which, when closed, completes a circuit to prove the presence of 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 condition. It should be set slightly below the minimum pressure, but not so close as to cause nuisance shutdowns.

The run/test switch on the program relay should be set to **TEST**. Turn the burner switch on. The blower will start (provided that all limit circuits are completed) and the programmer will proceed through the prepurge portion of the sequence, stopping at the low fire prepurge position.

NOTE: On an oil fired boiler, the atomizing air proving switch (AAPS) must also be closed.

On a combination fuel fired burner, the fuel selector switch could be set at "gas" to eliminate the atomizing air proving switch from the circuitry.

To have the modulating damper motor drive to high fire (damper open), remove the cover from the motor and remove the wire from terminal W.

Slowly turn down the air switch adjusting screw until it breaks the circuit. At this point the programmer will lockout and it must be manually reset before it can be restarted. Add a half turn or so to the adjusting screw to remake its circuit.

Recycle the program relay to be sure that normal operation is obtained. Replace the wire on terminal W and reinstall the cover. Return the test switch to the **RUN** position.

N. ATOMIZING AIR PROVING SWITCH

Air pressure against the diaphragm actuates the switch which, when closed, completes a circuit to prove the presence of atomizing air. Since the pressure of the atomizing air is at its minimum value when there is no fuel present at the nozzle, adjustment of the switch should be done while the unit is running but not firing. The control should be set slightly below the minimum pressure, but not so close as to cause nuisance shutdowns.

The control adjustment may be made during the prepurge period of operation by stopping the programmer during the prepurge period through the use of the **TEST** switch. Refer to the control instruction bulletin for details.

The adjustment screw of the atomizing air proving switch then can be adjusted until it breaks the circuit. At this point, the programmer will lockout and it must be manually reset before it can be restarted. Turn the adjusting screw up a half turn or so to remake the circuit.

Since the adjustment of the air switch may be made either during the damper closed or damper open position of prepurge, it is also possible to make the adjustment with the relay stopped in the damper open position in a similar manner to the adjustment of the combustion air proving switch described in the previous section.

After making the adjustment, recycle the control to be sure that normal operation is obtained. The **TEST** switch must be set to the **RUN** position.

O. GAS PILOT FLAME ADJUSTMENT

The size of the gas pilot flame is regulated by adjusting the gas flow through the pilot gas regulator and the adjusting cock. 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.

Although it is possible to visibly adjust the size of the pilot flame, it is preferable to obtain a microamp reading of the flame signal.

The amplifier of the standardly used program relay has a meter jack for this purpose. This reading may be measured with a good quality micro-ammeter or a suitable multi-meter with a 0 to 25 micro-amp DC rating.

The meter is connected to the jack using 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.

The program relay used may be of the type that provides message information that includes a constant flame signal of DC voltage. In this case a separate DC voltmeter is not required.

To Measure and Adjust Pilot:

(1) When making a pilot adjustment, turn the manual-automatic switch to "manual" and the manual flame control to "close." Open both the pilot shutoff cock and the pilot adjusting cock. The main gas cock should remain closed.

The regulator in the pilot line, if provided, reduces the gas pressure to suit the pilot requirement of between 5-10" W.C. The final adjustment of the pilot flame with the adjusting cock is less sensitive with a lower pilot pressure.

(2) Connect the micro-ammeter as outlined earlier.

(3) Turn the burner switch on. Let the burner go through the normal prepurge cycle. When the ignition trial period is signaled, set the test switch to the **TEST** position to stop the sequence.

(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, and with the pilot adjusting cock wide open, remove the flame detector from the burner plate. The pilot flame then can be observed through this opening.

!WARNING
Wear a protective shield or suitable glasses and keep eyes sufficiently away from the sight tube opening to avoid serious personal injury or death. Never remove the flame detector while the main burner is firing.

(6) To make the final adjustment, slowly close the gas pilot adjusting cock until the flame no longer can be seen through the sight tube. Then slowly open the cock 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, manually reset it. Replace the detector and repeat from step 5.

(7) When a suitable flame as indicated in number 6 is obtained, replace the detector. Observe the reading on the microammeter. The reading should be between 2-1/4 and 5 microamps when using a lead sulfide detector and a standard amplifier. See the flame signal table in the manufacturer's bulletin for values of other combinations.

The flame signal indicated on the annunciator type relay should not be less than 10 volts D.C. and many be as high as 20 or greater.

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) Return the test switch to the RUN position.

(9) If the main flame previously has not been established, proceed to do so in accordance with instructions elsewhere in the manual.

(10) The 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 flame at high, low, and intermediate firing rate positions. Readings should be steady and in the range indi-

cated in number 7. If there are any deviations, refer to the trouble shooting section in the technical bulletin.

P. 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 the 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. Since the gas pressure regulator itself is usually furnished by others, detailed adjustment instructions and adjusting procedures recommended by the manufacturer should be followed.

Pressure

The gas supplied must provide not only the quantity of gas demanded by the unit, but also must 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 (Figure 1-3) 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 1 for pressure requirements.

TABLE 1

Minimum Net Regulated Gas Pressure For Rated Boiler Output

(Pressure Required at Gas Train Entrance with Two Valves and 4" Pipe)		
Boiler	Regulated	Pressure
Horsepower	Standard	HTB
100	6.0" W.C.	—
125	7.0" W.C.	—
150	9.0" W.C.	—
200	15.0" W.C.	—
250	16.5" W.C.	22.0" W.C.
300	21.5" W.C.	26.5" W.C.
350	30.5" W.C.	37.5" W.C.
400	23.5" W.C.	33.5" W.C.

The pressures listed are based on 1000 BTU/CU.FT. natural gas at elevations up to 700 feet above sea level. For installation at higher altitudes, multiply the selected pressure by the proper factor from Table 2.

TABLE 2
(Altitude Correction Factor)

Altitude Feet Above Sea Level	Correction Factor
1000	1.04
2000	1.07
2500	1.09
3000	1.11
4000	1.16
5000	1.21
6000	1.25
7000	1.30
8000	1.35
9000	1.40

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 (BTU/HR.).

See Tables 3 and 4 for burner gas input requirements at high or low fire for standard or High Turndown Burners.

TABLE 3
(Standard Burner Required Input — Btu/Hr)

Boiler Horsepower	High Fire Input BTU/Hr	Minimum Low Fire Input BTU/HR
100	4,184,000	1,046,000
125	5,230,000	1,308,000
150	6,277,000	1,569,000
200	8,369,000	2,092,000
250	10,461,000	2,615,000
300	12,553,000	3,138,000
350	14,645,000	3,661,000
400	16,737,500	4,184,000

TABLE 4
(High Turndown Burner Required Input — BTU/Hr)

Boiler Horsepower	HighFire Input BTU/HR	Minimum LowFire Input BTU/HR
250	10,461,000	1,046,100
300	12,553,000	1,255,300
350	14,645,000	1,464,500
400	16,737,500	1,673,750

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 that 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 5.

TABLE 5
Pressure Correction Factors

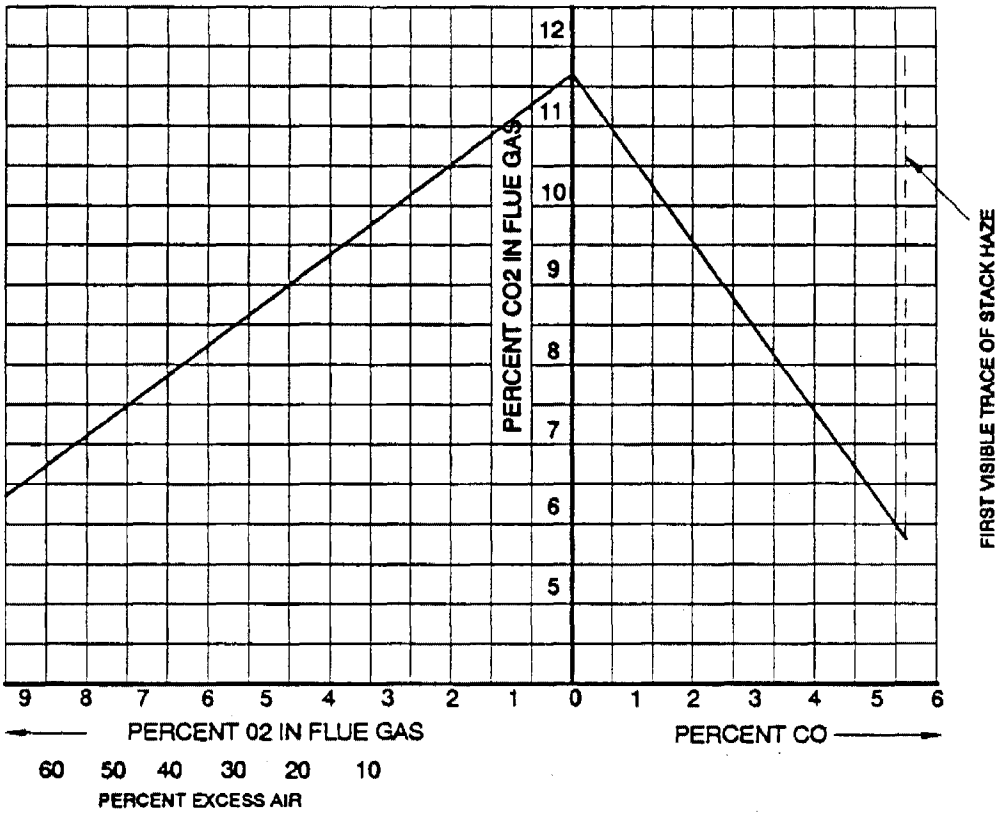
Regulator Inlet Pressure	Pressure Factor	Regulator Inlet Pressure	Pressure Factor
1 psig	1.05	9 psig	1.59
2 psig	1.11	10 psig	1.66
3 psig	1.18	11 psig	1.72
4 psig	1.25	12 psig	1.81
5 psig	1.32	13 psig	1.86
6 psig	1.39	14 psig	1.93
7 psig	1.45	15 psig	2.00
8 psig	1.53		

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 that must pass through the meter to deliver the equivalent number of cubic feet at base pressure.

As an example:
Assume that a 150 horsepower 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 9.5" W.C. gas pressure at sea level (Table 1). Table 2 indicates a correction factor of 1.13 for 2,000 feet. Multiplying these results in a calculated net regulated gas requirement of approximately 10.7" W.C. This is the initial pressure to which the regulator should be adjusted.



[FIGURE 5-4/FLUE GAS ANALYSIS CHART FOR NATURAL GAS]

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 3) and "correct" this answer by applying the correction factor for 3 psig (Table 4).

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

OR

$$\frac{6,277,000}{1,000} = 6,277 \text{ CFH (At 14.7 lb. atmospheric "base" pressure)}$$

THEN

$$\frac{6,277}{1.18} = 5,319 \text{ CFH}$$

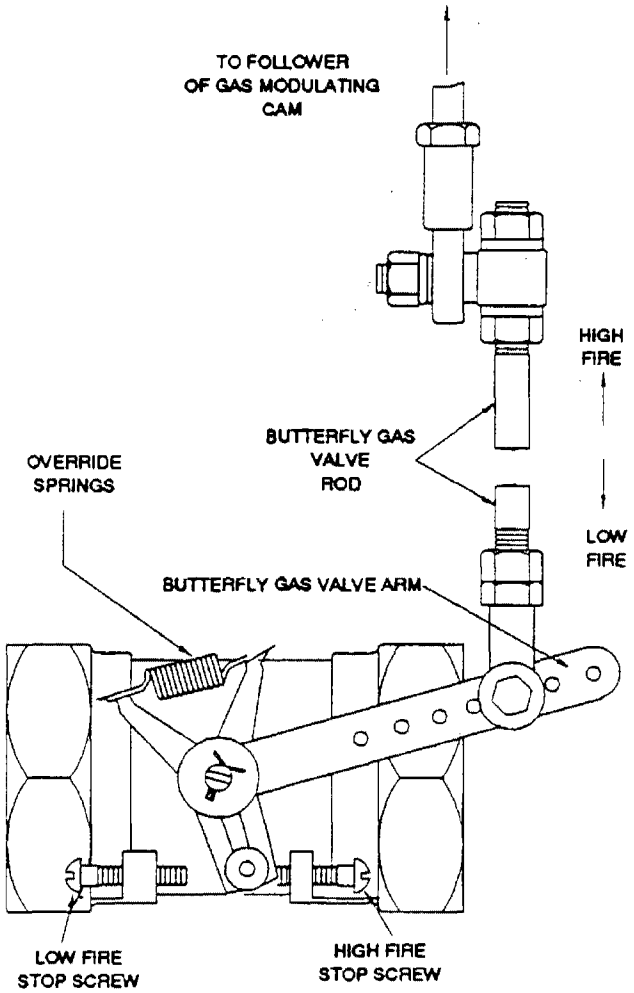
This is the CFH (at line pressure) which must pass through the meter so that the equivalent full input requirement of 6,277 CFH (at base pressure) will be delivered.

Checking Gas Flow

Your gas supplier generally can furnish a gas meter flow chart from which gas flow can be determined. After a short observation period, this information aids in adjusting the regulator to increase or decrease the flow as required to obtain the rating.

Final adjustment of gas fuel is carried out by means of the adjusting screws in the gas modulating cam while performing a combustion efficiency analysis. See Section Q for details.

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.



[FIGURE 5-5/BUTTERFLY GAS VALVE]

Q. GAS FUEL COMBUSTION ADJUSTMENT

After operating for a sufficient period of time to assure a warm boiler, adjustments should be made to obtain efficient combustion.

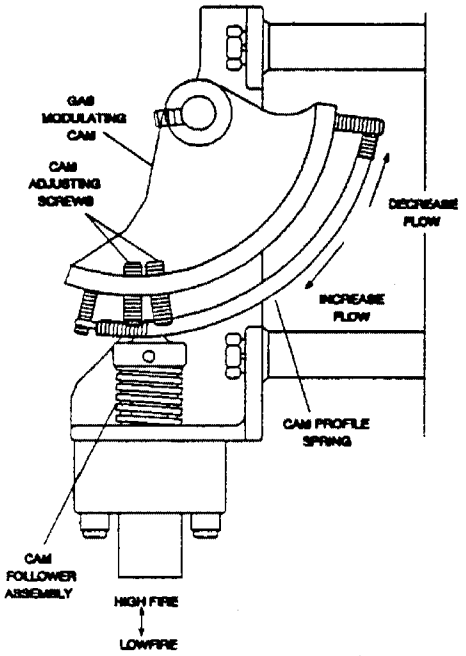
The appearance or color of the gas flame is not an indication of its efficiency since an efficient gas flame will vary from transparent blue to translucent yellow.

Proper setting of the air/fuel ratios at all firing rates must be established by use of a combustion gas analyzer. This instrument measures the content, by percentage, of either carbon dioxide (CO_2), or oxygen (O_2), and carbon monoxide (CO) in the flue gas.

Burner efficiency is measured by the amount or percentage of CO_2 present in the flue gas. The theoretical maximum CO_2 percentage for natural gas is approximately 11.7%. As shown in Fig. 5-4, this is attained when there is no excess oxygen (O_2) or carbon monoxide (CO). A definite percentage of excess air (oxygen) is required by most local authorities and of course, the burner always should be operated with an air/fuel ratio at which the minimum percentage of CO is produced.

Subject to local regulations pertaining to specific amounts of excess oxygen, it generally is recommended that CO_2 readings of between 9-1/2 and 10% be attained with corresponding O_2 readings of 4 to 3% at high fire.

From information in section P of this chapter, determine the standard conditions of gas pressure and flow for the size boiler and the gas train on it. Calculate the actual pressure and flow through the use of correction factors that compensate for incoming gas pressure and altitude.



[FIGURE 5-6 GAS MODULATING CAM]

Basically, gas adjustments are made with a gas pressure regulator (Figure 1-15) that controls the pressure and with the butterfly gas valve (Figure 1-3) that directly controls the rate of flow.

In initially setting the linkage, back off the low fire stop screw on the butterfly valve so that the valve is closed. Then run the screw out to touch the arm and give it two complete turns. Adjust the connecting rod so that the override tension is released and so that the arm now is just touching the stop screw. Tighten the lock nuts on all ball joints. See Figure 5-5.

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

To reach the high fire rate, turn the manual flame control switch toward "OPEN" in minor increments while monitoring combustion for overly rich or lean conditions.

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

Determine the actual gas flow from a meter reading. See section P of this chapter. With the butterfly valve open and with the regulated gas pressure set at the calculated pressure, the actual flow rate should be quite close to the required input. If corrections are necessary, increase or decrease the gas pressure by adjusting the gas pressure regulator, following the manufacturer's directions for regulator adjustment.

When proper gas flow is obtained, perform a flue gas analysis. The CO_2 value should be between 9.5-10% with a corresponding O_2 value of 4-3% at high fire.

If the fuel input is correct, but the CO_2 and O_2 values do not fall within these ranges, the air damper travel may need to be adjusted. Adjustment of the air damper linkage is described in Section B of this chapter.

With the high fire air-fuel ratio established, the gas pressure regulator needs no further adjusting.

After making certain that the air control damper and its linkage are correctly adjusted to provide the proper amount of secondary air and after adjusting the gas pressure regulator, final adjustment can be made, if necessary, to the gas modulating cam to obtain a constant air-fuel ratio throughout the entire firing range.

Since the input of combustion air is ordinarily fixed at any given point in the modulating cycle, the flue gas reading is determined by varying the input of gas fuel at that setting. This adjustment is made to the metering cam by means of adjusting screws that are turned out (counterclockwise from the hex-socket end) to increase the flow of fuel, and in (clockwise from the hex-socket end) to decrease it. Flow rate is highest when the cam follower assembly is closest to the jackshaft. See Figure 5-6.

Through the manual flame control switch, position the cam so that the adjusting screw adjacent to the end or high fire screw contacts the cam follower. Perform a combustion analysis at this point. If an adjustment is necessary, turn the adjustment screw accordingly to increase or decrease the fuel flow. Take a combustion reading to verify the input. Repeat as necessary until the desired flow is obtained. Repeat this process, stopping at each adjusting screw, until the low fire adjusting screw is reached.

CAUTION!

Do not use any lubricant on the adjusting setscrews. These have a nylon locking insert intended to provide locking torque and resistance to loosening and could damage equipment.

Standard Burner
Low Fire Adjustment

With the low fire cam screw, the fuel input should be adjusted to approximately 25% of that at high fire (Table 3). At low fire the CO_2 flue gas content should be 8.8-9.1% with 4-4.5% O_2.

It may be necessary to readjust the setting of the low fire stop screw in order to obtain the proper air/fuel ratio at the low fire rate. To ensure that the low fire position of the gas butterfly valve is always the same, allow one turn of the stop screw for overtravel.

If the air damper needs to be adjusted in order to provide the correct low fire air/fuel ratio, combustion must be rechecked at higher firing rates and adjusted as required.

If all cam screws are properly adjusted, none will deviate from the general overall contour of the cam face.

High Turndown Burner
Low Fire Adjustment

With the low fire cam screw, gas flow should be adjusted to obtain a minimum fuel input 10% of that at high fire (Table 4). The resulting flue gas CO_2 content should be 5.8-6.7% with a corresponding O_2 content of 11-9.5%.

It may be necessary to readjust the setting of the low fire stop screw in order to obtain the proper air/fuel ratio at low fire. To ensure that the low fire position of the gas butterfly valve is always the same, allow a half turn of the stop screw for overtravel.

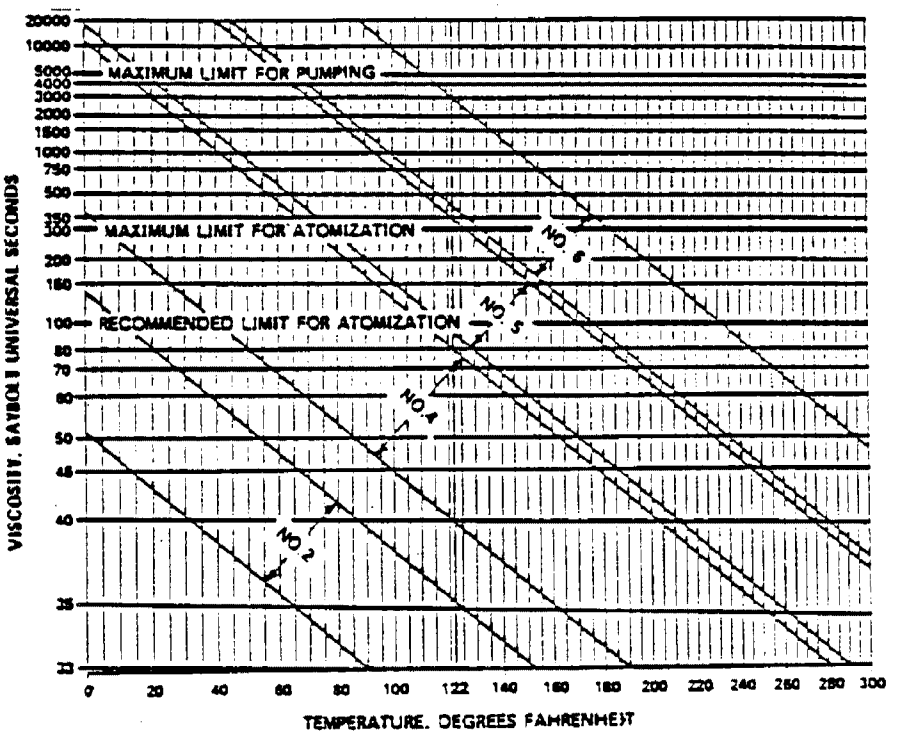
If the air damper must be reset to meet the low fire air/fuel requirements, combustion at higher firing rates must be rechecked.

The second cam adjusting screw may need to be adjusted in order to maintain a smooth cam profile. If all screws are properly adjusted, none will deviate from the general overall contour of the cam face.

R. LOW GAS PRESSURE SWITCH

Adjust the scale setting to slightly below the normal burning pressure. The control circuit will be broken when the pressure falls below this point. Since gas line distribution pressure may decrease under some conditions, shutdowns may result if the setting is too close to normal. However, regulations require that the setting may not be less than 50% of the rated pressure downstream of the regulator.

Manual resetting is necessary after a pressure drop. Press the reset lever after the pressure is restored. Make sure that a mercury switch equipped control is level.



[FIGURE 5-7/OIL VISCOSITY CHART]

S. HIGH GAS PRESSURE SWITCH

Adjust the scale setting to slightly above the normal burning pressure. The control circuit will be broken when pressure exceeds this point. Unnecessary shutdowns may result if the setting is too close to normal, however, regulations require that the setting may not be greater than 50% of the rated pressure.

Manual resetting is necessary after a pressure rise. Press the reset lever after the pressure falls. Make sure that a mercury switch equipped control is level.

T. FUEL OIL PRESSURE AND TEMPERATURE - GENERAL

Variations in burning characteristics of the fuel oil may require adjustments from time to time to assure highest combustion efficiency. The handling and burning characteristics may vary from one delivery of oil to another. For this reason, it is recommended that the oil system be inspected from time to time to verify that pressures and viscosity are at the proper operating levels.

Because of variation in oils including chemical content, source, blends and viscosity characteristics, the temperatures and pressures listed in Chapter 4 and mentioned in the adjusting of the controls in the following paragraphs will vary and thus may be regarded as tentative and may need to be changed to provide best firing conditions. Figure 5-7 is an oil viscosity-temperature chart. This may be used as a guide, although your oil supplier will be able to give you more exacting information based on an analysis of the oil.

Review of the applicable maintenance instructions given in Chapter 7 will aid in maintaining an efficient fuel system.

NOTE: To prevent oil heater coking, the fuel oil pump must be in operation during all times that an oil heater is in service. During any time that the oil pump is not operating, the oil heating system must be electrically shut down by manually turning the oil heater switch to the "off" position.

When the boiler is shut down, or switched over to gas firing, the pump must operate for a sufficient period of time to cool the oil heater. Similarly, if an electric, steam, or hot water oil heater is removed for servicing, the temperature of the heater should be reduced by circulating oil until it has cooled.

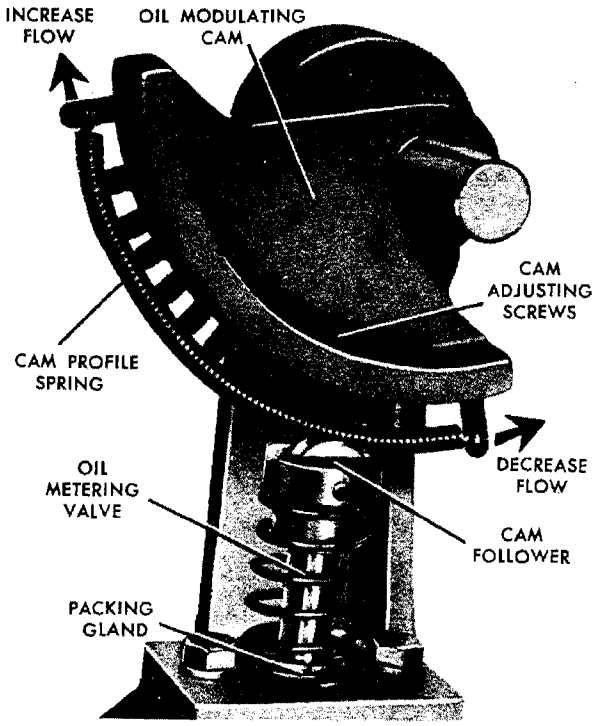
U. FUEL OIL COMBUSTION ADJUSTMENT

After operating for a sufficient period of time to assure a warm boiler, adjustments should be made to obtain efficient combustion.

Efficient combustion cannot solely be judged by flame condition or color, although they may be used in making approximate settings. This should be done so that there is a bright sharp flame with no visible haze.

Proper setting of the air/fuel ratios at all firing rates must be established by the use of a combustion gas analyzer. This instrument measures the flue gas content, by percentage, of either carbon dioxide (CO_2), or oxygen (O_2), and in some cases, smoke.

Burner efficiency is determined by the amount, by percentage, of CO_2 or O_2 present in the flue gas. The ideal setting from an efficiency standpoint is reached when the percentage of oxygen in the flue gas is zero. 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, temperature, or burning properties of the oil. Fifteen to twenty percent excess air is considered reasonable and this should result in an approximate CO_2 value of 12.5-13% for No. 2 oil and 13.5-14% for No. 6 oil with an O_2 value of 3.5-3%.



[FIGURE 5-8/ OIL MODULATING CAM]

Final adjustment to fuel input must be made to produce a minimum of smoke. A maximum smoke spot density of a No. 2 for light oil, or a No. 4 for heavy oil is acceptable, as measured in conformance to ASTMD 2156-63T.

Through the use of the manual flame control, slowly bring the unit to high fire by stages while monitoring combustion for overly rich or lean conditions. At the high fire position, the air damper should be fully opened and the air and oil pressure readings should be on the order of those given in Chapter 4.

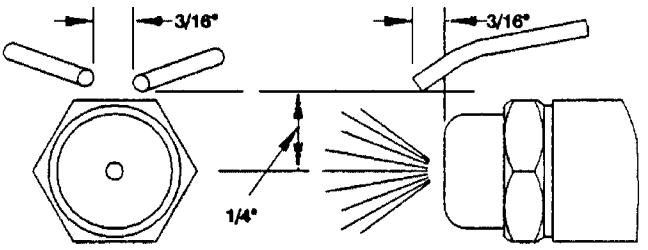
Take a flue gas analysis reading at this point. If necessary, make adjustments to the fuel oil controller to increase or decrease oil pressure. This should be done before making any effort to adjust the screws in the metering cam. Ideally, the cam profile spring should be as close to the cam casting as practical and it is more desirable to lower the oil pressure to reduce flow, if necessary, than to extend adjusting screws to an extreme position in an effort to cut back on flow.

After making certain that the air control damper and its linkage are operating properly to provide the proper amount of secondary air and that fuel oil pressure settings are correct, final adjustment can be made, if necessary, to the oil modulating cam to obtain a constant fuel-air ratio through the entire firing range.

Since the input of combustion air is ordinarily fixed at any given point in the modulating cycle, the flue gas reading is determined by varying the input of fuel at that setting. This adjustment is made to the metering cam by means of adjusting screws, which are turned out (counterclockwise from hex-socket end) to increase the flow of fuel and in (clockwise from hex-socket end) to decrease it. Flow rate is highest when the cam follower assembly is closest to jackshaft. See Figure 5-8.

If oil pressure, primary air pressure, and linkages are properly adjusted, the metering cam should require minimal adjustment.

If adjustment is necessary, follow this recommended procedure.



[FIGURE 5-9/ ELECTRODE SETTING — OIL PILOT]

Through the flame control switch, position the cam so that the adjusting screw adjacent to the end or high fire screw contacts the cam follower. Make a combustion analysis at this point.

If an adjustment is necessary, turn the adjustment screw accordingly to increase or decrease fuel flow. Take a combustion reading to verify input. Repeat as necessary until the desired flow is obtained. Continue this process, stopping at each adjusting screw, until the low fire position is reached.

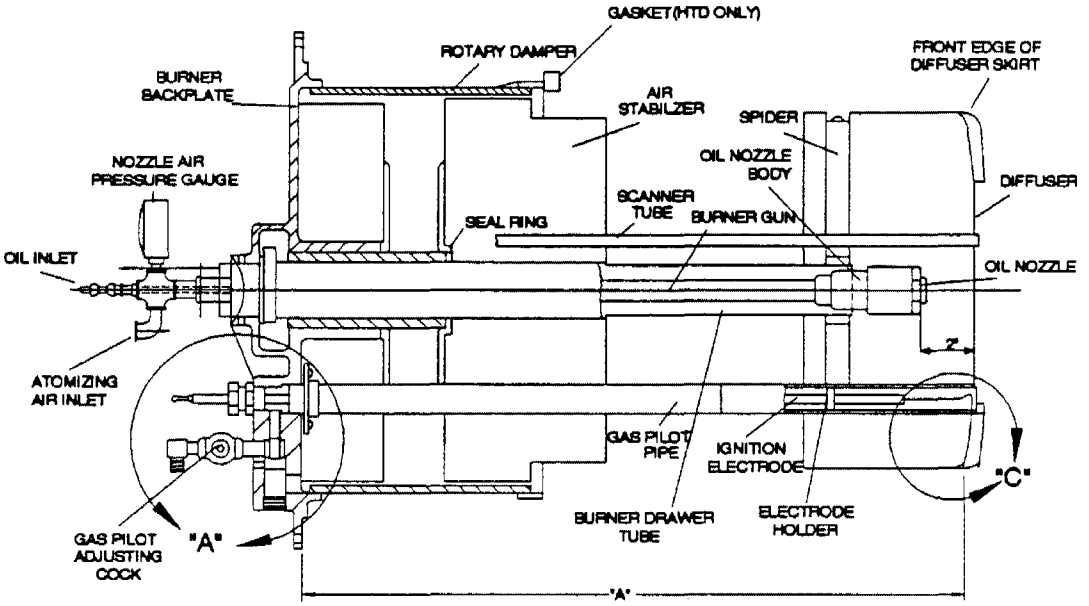
CAUTION!

Do not use any lubricant on the adjusting setscrews. These have a nylon locking insert intended to provide locking torque and resistance to loosening and a lubricant could damage the equipment.

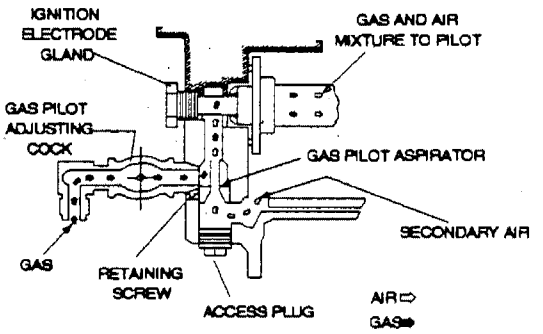
Standard Burner

Low Fire Adjustment (Heavy Oil)

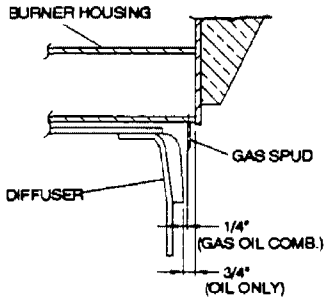
Fuel input at low fire should be approximately 25% of that at high fire, with final adjustment being made to optimize combustion. If all cam screws are properly adjusted, none will deviate from the general contour of the cam face.



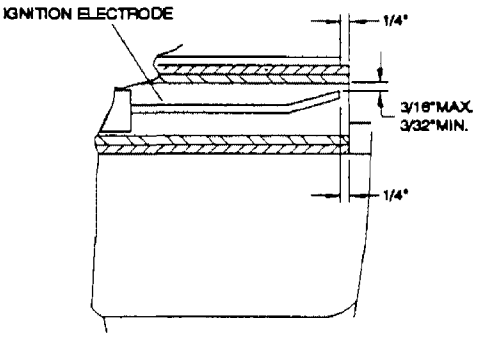
BURNER	DIMENSION "A"
ST'D 100-200HP	16-3/4"
ST'D 250-400HP	25-5/8"
HTD 250-400HP	22-1/8"



DETAIL "A"



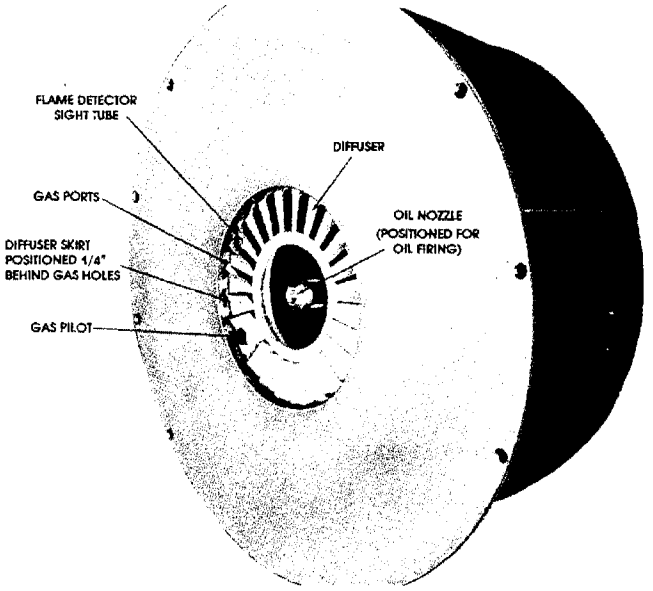
DETAIL "B" - HIGH TURNDOWN (250-400HP)



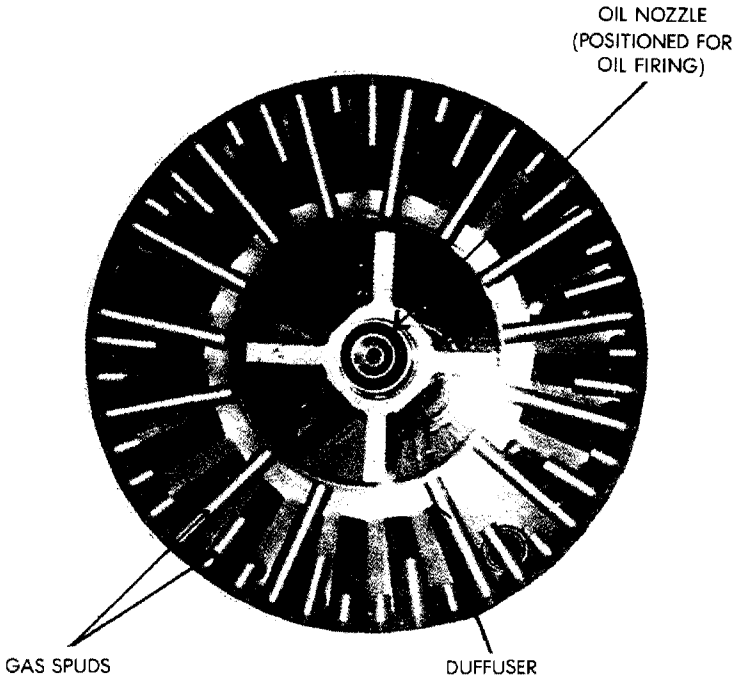
DETAIL "C"

[FIGURE 5-10/BURNER DRAWER WITH GAS PILOT]

Standard Burner



High Turndown Burner



[FIGURE 5-11/BURNER HOUSINGS]

High Turndown Burner Low Fire Adjustment (Light Oil)

Fuel input at low fire should be approximately 12.5% of that at high fire. The low fire cam screw should be adjusted to obtain this flow rate with resulting flue gas content of 8.5-9.5% CO_2 and 9.3-7.8% O_2. The second cam adjusting screw may need to be adjusted in order to maintain a smooth cam profile.

At the low fire screw, the oil flow should be adjusted to obtain the necessary input for the fuel turndown required. The second adjusting screw may need to be adjusted in order to maintain a smooth cam profile.

V. BURNER DRAWER ADJUSTMENT

There are relatively few adjustments that can be made to the burner. However, a check should be made to see that all components are properly located and that all holding screws are properly tightened. Figures 5-10 and 5-11 show various views or portions of the burner.

The diffuser location on gas fired boilers is quite important. There should be 1/4" between the edges of the diffuser fins and the gas outlet tubes (spuds). (See Figure 5-11) The setting of an oil fired burner is less exacting and the diffuser should be located with the skirt approximately 1-1/8" from the end of the burner tube.

When the proper diffuser location is ascertained, the setting of the nozzle in relation to the diffuser should be checked. This generally is set at the time of manufacture and seldom needs altering. It is most important that oil spray does not impinge upon the diffuser. The distance that the nozzle is behind the diffuser has some latitude and individual installations may require a slight deviation. The spacing indicated is 2".

Check the setting of the ignition electrode(s) for proper gap and position. See Figure 5-10 for the gas pilot electrode and Figure 5-9 for the light oil pilot. Make sure that the porcelain insulator is not cracked and that the ignition cable connections are tight.

The oil nozzle tip should be seated tightly in the body with the swirler and the seating spring in place. See Section G in Chapter 7 for additional nozzle tip information.

Check to see that the flame detector sight tube and the gas pilot tube extend through their respective openings in the diffuser face.

W. OIL DRAWER SWITCH

The integral contacts of this control are closed by proper positioning and latching of the oil drawer in its forward position. Adjustment of the switch must be such that its contacts open if the oil drawer is not properly positioned for oil firing. The switch is electrically removed from the circuit when a combination fuel burner is fired on gas.

X. LOW OIL TEMPERATURE SWITCH

This control prevents the burner from starting, or stops its operation, if the temperature of the oil is below the normal operating temperature.

To adjust this control, insert a screwdriver into the center slot in the control cover and turn the dial until the fixed (center) pointer is approximately 30°F lower than the oil heater thermostat setting. Turn the differential adjusting screw (located above the dial) until the movable indicator is approximately 5° F above the setting on the main scale.

On a hot water boiler, the low oil temperature switch is an integral part of the electric oil heater. The switch is nonadjustable and is factory set at approximately 40° F below the maximum operating temperature of the heater.

Y. HIGH OIL TEMPERATURE SWITCH (OPTIONAL)

This control prevents the burner from starting, or stops its operation, if the temperature of the oil exceeds the normal operating temperature.

To adjust, turn the dial until the pointer is approximately 25° F above the normal operating temperature. These controls generally have a set differential and will close 5° F below the set point.

Z. LOW OIL PRESSURE SWITCH (OPTIONAL)

This control prevents burner ignition, or stops its operation, when the oil pressure is below a set point. Adjust the control by turning the screw on top of the control case to an indicated pressure 10 psi below the established primary oil pressure setting indicated on the oil supply pressure gauge. The switch will remain in a closed position as long as the oil pressure exceeds this setting. The control normally used automatically resets when pressure is restored after a drop.

AA. ELECTRIC OIL HEATER THERMOSTAT (400 and 600 Series - Steam)

The maximum temperature setting of the control is stamped on the dial. This is attained with the adjusting knob turned to the "high" end of the scale. Lower settings are obtained by turning the adjusting knob clockwise, using the thermometer in the fuel oil controller as a guide.

The final setting of this thermostat should be at a temperature approximately 15° lower than the steam heater thermostat. This prevents electric heater operation when the steam heater is functioning. The electric heater is sized to provide sufficient heated oil for low fire operation on cold starts before steam is available.

A 0.005 MFD capacitor is wired in parallel with the thermostat lead connections to prevent contact bounce and arcing. The control differential is nonadjustable.

BB. STEAM OIL HEATER THERMOSTAT (No. 6 Oil) (400 and 600 Series — Steam)

The maximum temperature setting of the control is stamped on the dial. This is attained with the adjusting knob turned to the "high" end of the scale. Lower settings are obtained by turning the adjusting knob clockwise using the thermometer in the fuel oil controller as a guide.

The final setting of this thermostat should provide oil at a sufficient temperature for efficient combustion based on the flue gas analysis. There is no need to heat the oil in excess of this temperature.

A 0.005 MFD capacitor is wired in parallel with the thermostat lead connections to prevent contact bounce and arcing. The control differential is nonadjustable.

CC. HOT WATER OIL HEATER THERMOSTAT (400 and 600 Series)

To adjust, insert a screwdriver into the center slot in the control cover and turn the dial until the pointer is at the desired temperature level. This control generally has a set differential and will close 5°F below the set point.

The thermostat contacts close to energize the booster water pump, which pumps water from the boiler through the heater. On cold starts, it is normal practice to manually close the valve in the pump discharge line until the boiler water temperature exceeds the temperature of the fuel oil entering the heater.

The electric oil heater on a hot water boiler burning No. 6 oil and equipped with a hot water oil heater has a built-in adjustable thermostat. The maximum temperature setting is stamped on its dial. The desired temperature can be obtained by turning the adjusting screw. The thermostat should be set at a temperature approximately 15 degrees lower than the hot water heater thermostat. This prevents electric heater operation when the water heater is functioning. The electric heater is sized to provide sufficient heated oil for low fire operation on cold starts before hot water is available.

DD. STEAM HEATER PRESSURE REGULATOR (400 and 600 Series - Steam)

This regulator is provided on a boiler designed to operate at boiler pressures above 15 psi for the purpose of reducing boiler steam pressure to the level necessary for proper operation of the steam oil heater. This pressure should be reduced to a point that permits sufficient temperature to heat the oil while allowing as continuous a steam flow as possible. Pressure that is too high will result in frequent cycling of the steam solenoid valve.

It is best to adjust the regulator under typical flow conditions. To do this, it is suggested that the globe valve in the steam supply line be closed so that there is no pressure on the regulator. Turn out the adjusting screw fully to relieve compression on the regulator spring, thus closing the regulator. With steam at normal pressure, open the globe valve and then set the secondary pressure by turning the adjusting screw or handle until the downstream gauge shows the desired pressure.

CHAPTER 6

TROUBLE SHOOTING

A. Burner Does Not Start
B. No Ignition
C. Pilot Flame, But No Main Flame
D. Burner Stays in Low Fire
E. Shutdown Occurs During Firing
F. Modulating Motor

!WARNING
Trouble shooting should be performed only by personnel who are familiar with the equipment and who have read and understand the contents of this manual. Ifyou have questions, contact your local Cleaver-Brooks authorized Representative for assistance. Failure to heed this warning could result in serious personal injury or death.

!WARNING
Disconnect and lock out the main power supply in order to avoid the hazard of electrical shock, which could result in serious personal injury or death.

NOTE: If your boiler is equipped with a CB-HAWK™ boiler management control system, refer to CB-HAWK Installation, Operating and Servicing Manual No. 750-133 for specific information regarding procedures described in this section.

This section assumes that the unit has been properly installed and adjusted, and that it has been running for some time. It is further assumed that the operator has become thoroughly familiar with both the burner and the manual by this time. The points under each heading are set down as 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 if it will not operate properly, this trouble shooting section 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 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 trouble shooting 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.

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) No voltage at the program relay power input terminals.

(a) Main disconnect switch open.

(b) Blown control circuit fuse.

(c) Loose or broken electrical connection.

(2) Program relay safety switch requires resetting.

(3) Limit circuit is not completed — no voltage at end of limit circuit program relay terminal.

(a) Pressure or temperature is above setting of operation control. (Load demand light will not glow.)

(b) Water below required level.

(i) Low water light (and alarm horn) should indicate this condition.

(ii) Check manual reset button, if provided, on low water control.

(c) Fuel pressure must be within settings of low pressure and high pressure switches.

(d) Oil fired unit — burner gun must be in full forward position to close oil drawer switch.

(e) Heavy oil fired unit — oil temperature below minimum setting.

(4) Fuel valve interlock circuit not completed.

(a) Fuel valve auxiliary switch not closed.

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) Insufficient or no voltage at pilot ignition circuit terminal.

(2) Spark but no flame.

(a) Lack of fuel — no gas pressure, closed valve, empty tank, broken line, etc.

(b) Inoperative pilot solenoid.

(c) Insufficient or no voltage at pilot ignition circuit terminal.

(d) Too much air.

(3) Low fire switch open in low fire proving circuit.

(a) Damper motor not closed, slipped cam, defective switch.

(b) Damper jammed or linkage binding.

(4) Running interlock circuit not completed.

(a) Combustion or atomizing air proving switches defective or not properly set.

(b) Motor starter interlock contact not closed.

(5) Flame detector defective, sight tube obstructed, or lens dirty.

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.

(c) Gas pressure regulator inoperative.

(3) Oil fired unit.

(a) Oil supply cut off by obstruction, closed valve, or loss of suction.

(b) Supply pump inoperative.

(c) No fuel.

(d) Main oil valve inoperative.

(e) Check oil nozzle, gun and lines.

(4) Insufficient or no voltage at main fuel valve circuit terminal.

(5) Flame detector defective, sight tube obstructed or lens dirty.

D. BURNER STAYS IN LOW FIRE

(1) Pressure or temperature above modulating control setting.

(2) Manual-automatic switch in wrong position.

(3) Inoperative modulating motor (see Section F).

(4) Defective modulating control.

(5) Binding or loose linkage, cams, setscrews, etc.

E. SHUTDOWN OCCURS DURING FIRING

(1) Loss or stoppage of fuel supply.

(2) Defective fuel valve; loose electrical connection.

(3) Flame detector weak or defective.

(4) Lens dirty or sight tube obstructed.

(5) If the programmer lockout switch has not tripped, check the limit circuit for an opened safety control.

(6) If the programmer lockout switch has tripped:

(a) Check fuel lines and valves.

(b) Check flame detector.

(c) Check for open circuit in running interlock circuit.

(d) The flame failure light is energized by ignition failure, main flame failure, inadequate flame signal, or open control in the running interlock circuit.

(7) Improper air-fuel ratio (lean fire).

(a) Slipping linkage.

(b) Damper stuck open.

(c) Fluctuating fuel supply.

(i) Temporary obstruction in fuel line.

(ii) Temporary drop in gas pressure.

(iii) Orifice gate valve accidentally opened (heavy oil).

(8) Interlock device inoperative or defective.

F. MODULATING MOTOR DOES NOT OPERATE

(1) Manual-automatic 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) Motor defective.

(b) Loose electrical connection.

(c) Damper motor transformer defective.

(4) Motor does not operate on demand.

(a) Manual-automatic switch in wrong position.

(b) Modulating control improperly set or inoperative.

(c) Motor defective.

(d) Loose electrical connection.

(e) Damper motor transformer defective.

CHAPTER 7

INSPECTION AND MAINTENANCE

A. General
B. Fireside Cleaning
C. Water Level Controls and Waterside
D. Water Gauge Glass
E. Electrical Controls
F. Flame Safegaurd Control
G. Oil Burner Maintenance
H. Gas Burner Maintenance
I. Motorized Gas Valve
J. Solenoid Valves
K. Air Control Damper, Linkage and Cam Spring
L. Forced Draft Fan
M. Safety Valves
N. Fuel Oil Valves
O. Air Pump and Components
P. Refractory
Q. Opening and Closing Doors
R. Lubrication
S. Oil Heaters — Electric, Steam, Hot Water
T. Combustion

NOTE: For more information on your flame safeguard system, refer to the appropriate manual that was provided with your boiler.

!WARNING
Inspection and maintenance should be performed only by trained personnel who are familiar with this equipment. Failure to heed this warning could result in serious personal injury or death.

A. GENERAL

A well-planned maintenance program will help avoid unnecessary down-time or costly repairs, promote safety, and aid boiler 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 of daily, weekly, monthly, and yearly maintenance activities provides a valuable guide and aids in obtaining economical and lengthy service from Cleaver-Brooks equipment. A boiler inspection schedule is shown at the end of this chapter in Fig. 7-13, which can be used as a guide. It is important to realize that the frequency of inspection will depend on variable conditions; such as, load, fuel, system requirements, boiler environment (indoor/outdoor), etc.

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.

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" feature does not relieve the operator from responsibility, but rather frees him of certain repetitive chores providing him time to devote to upkeep and maintenance.

Alertness in recognizing an unusual noise, improper gauge reading, leak, etc., can make the operator aware of a developing malfunction, permitting prompt corrective action that may prevent extensive repairs or unexpected down-time. Any leaks — fuel, water, steam, exhaust gas — should be repaired and under conditions that observe necessary safety precautions. Preventive maintenance measures such as regularly checking the tightness of connections, locknuts, setscrews, packing glands, etc., should be included in regular maintainance activities.

Periodic Inspection

Insurance regulations or local laws require a periodic inspection of the pressure vessel by an authorized inspector. Section I of Chapter 2 contains information relative to this inspection.

Inspections of this type are usually, though not necessarily, scheduled for periods of normal boiler down-time such as an off season. This major inspection can often be used to accomplish maintenance, replacement, 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 a detailed inspection and check of all components of the boiler, including; piping, valves, pumps, gaskets, refractory, etc. Complete 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.

CAUTION!

Cleaver-Brooks genuine parts should be used to ensure proper operation and avoid damage to equipment.

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

The Cleaver-Brooks Total Protection Plan includes a Planned Maintainance Program that covers many of the items included in this chapter.

For information regarding the Total Protection Plan, contact your Cleaver-Brooks local authorized representative.

B. 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 that will deteriorate fireside metal.

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

Tube cleaning is accomplished by opening front and rear doors. Tubes may be brushed from either end. All loose soot and accumulations should be removed. Any soot or other deposits should be removed from the furnace and the tube sheets.

Refer to Section Q of this chapter for instructions on properly opening and closing rear head.

The flue gas outlet and stack should be inspected annually and cleaned as necessary. Commercial firms are available to perform this work. The stack should also 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. See Section J in Chapter 2.

C. WATER LEVEL CONTROLS

The need to periodically check water level controls and the waterside of the pressure vessel cannot be overemphasized. 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. On steam boilers, the water column should be blown down daily. Check samples of boiler water and condensate in accordance with procedures recommended by your water consultant. Refer to Sections H and I in Chapter 2 for blowdown instructions and internal inspection procedures.

Since low water cut-off devices are generally set by the original manufacturer, no attempt should be made to adjust these controls to alter the point of low water cut-off 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 previously established levels, contact your Cleaver-Brooks local authorized representative for assistance.

Steam Boiler

Fig. 7-1 is a replica of the low water cut-off plate attached to a steam boiler. These instructions should be followed on a definite schedule. 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.

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

WARNING

SAFE OPERATION OF YOUR GENERATOR DEMANDS PERIODIC INSPECTION AND MAINTENANCE OF ALL LOW WATER CUT-OFF DEVICES. OPEN AND INSPECT THEM AT LEAST ONCE A MONTH. UNDER CONSTANT ATTENDANCE AND WITH BURNER IN LOW FIRE POSITION, CHECK OPERATION FREQUENTLY BY STOPPING WATER FLOW TO GENERATOR, AND ALLOWING WATER LEVEL TO LOWER. IF CONTROLS DO NOT CUT OFF BURNER AT PROPER SAFE WATER LEVEL OR APPEAR IN POOR PHYSICAL CONDITION, REPAIR OR REPLACE AT ONCE.

[FIGURE 7-1 / LOW WATER PLATE]

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. Verify that piping is vertically aligned.

A blowdown of the water controls on a steam boiler should be performed daily.

Hot Water Boiler

It is impractical to blowdown the low water cut-off 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 cut-off devices, it is essential to verify proper operation and remove the operating mechanism from the bowl annually or more frequently, if possible, to check and clean the 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 should 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.

It is recommended that the boiler is off and cool when the gauge glass is replaced, however if the glass is replaced while the boiler is in service, open the blowdown and slowly bring the glass to operating temperature by opening the gage valves slightly. After the glass is warmed up, close the blowdown valve and open the gauge valves completely.

!WARNING

Use care when changing the gauge glass while the boiler is in service. Wear protective clothing and eye protection to avoid serious personal injury or death.

Check try-cocks and gauge cocks for 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.

E. ELECTRICAL CONTROLS

The operating controls should be inspected monthly. Examine the tightness of electrical connections and keep the controls clean. Remove any dust that accumulates on the interior of the control using low pressure air. Take care not to damage the mechanism.

Examine any mercury tube switches for damage or cracks. Dark scum over the normally bright surface of the mercury may lead to erratic switching action. Make certain that controls are correct-

RECOMMENDED MAXIMUM "FUSETRON" FUSE SIZES

ELECTRICAL LOAD	SINGLE PHASE 50/60 HERTZ		THREE PHASE 50/60 HERTZ				
	110-120 V	220-240 V	200-208 V	220-240 V	346-416 V	440-480 V	550-600V
1/4 HP MOTOR	FRN - 8	FRN - 4-1/2	FRN - 1-8/10	FRN - 1-8/10		FRS - 1	FRS - 8/10
1/3 HP MOTOR	FRN - 9	FRN - 4-1/2	FRN - 1-8/10	FRN - 1-8/10		FRS - 1	FRS - 8/10
1/2 HP MOTOR	FRN - 12	FRN - 6-1/4	FRN - 2-8/10	FRN - 2-8/10	FRS - 1-8/10	FRS - 1-4/10	FRS - 1
3/4 HP MOTOR	FRN - 17-1/2	FRN - 9	FRN - 4-1/2	FRN - 4-1/2	FRS - 2-1/4	FRS - 1-8/10	FRS - 1-4/10
1 HP MOTOR	FRN - 20	FRN - 10	FRN - 5	FRN - 5	FRS - 3-2/10	FRS - 2-1/4	FRS - 1-8/10
1-1/2 HP MOTOR	FRN - 25	FRN - 12	FRN - 7	FRN - 7	FRS - 4	FRS - 3-2/10	FRS - 2-1/2
2 HP MOTOR	FRN - 30	FRN - 15	FRN - 9	FRN - 9	FRS - 5-6/10	FRS - 4-1/2	FRS - 3-1/2
3 HP MOTOR	FRN - 40	FRN - 20	FRN - 12	FRN - 12	FRS - 8	FRS - 6-1/4	FRS - 5
5 HP MOTOR		FRN - 35	FRN - 20	FRN - 20	FRS - 12	FRS - 10	FRS - 8
7-1/2 HP MOTOR		FRN - 50	FRN - 30	FRN - 30	FRS - 17-1/2	FRS - 15	FRS - 12
10 HP MOTOR		FRN - 60	FRN - 40	FRN - 35	FRS - 20	FRS - 17-1/2	FRS - 15
15 HP MOTOR			FRN - 60	FRN - 50	FRS - 30	FRS - 25	FRS - 20
20 HP MOTOR			FRN - 70	FRN - 70	FRS - 40	FRS - 35	FRS - 25
25 HP MOTOR			FRN - 90	FRN - 80	FRS - 50	FRS - 40	FRS - 35
30 HP MOTOR			FRN - 100	FRN - 100	FRS - 60	FRS - 50	FRS - 40
40 HP MOTOR			FRN - 150	FRN - 150	FRS - 80	FRS - 70	FRS - 50
50 HP MOTOR			FRN - 175	FRN - 175	FRS - 100	FRS - 80	FRS - 70
60 HP MOTOR			FRN - 200	FRN - 200	FRS - 125	FRS - 100	FRS - 80
75 HP MOTOR			FRN - 250	FRN - 250	FRS - 150	FRS - 125	FRS - 100
100 HP MOTOR			FRN - 350	FRN - 300		FRS - 150	FRS - 125
125 HP MOTOR			FRN - 450	FRN - 400		FRS - 200	FRS - 150
150 HP MOTOR			FRN - 500	FRN - 450		FRS - 225	FRS - 200
200 HP MOTOR				FRN - 600		FRS - 300	FRS - 250
2 KW HEATER	FRN - 20	FRN - 12	FRN - 7	FRN - 7		FRS - 4-1/2	FRS - 3-2/10
3 KW HEATER	FRN - 30	FRN - 15	FRN - 10	FRN - 10	FRS - 6-1/4	FRS - 5-6/10	FRS - 4-1/2
5 KW HEATER	FRN - 50	FRN - 25	FRN - 15	FRN - 15	FRS - 10	FRS - 8	FRS - 6-1/4
7-1/2 KW HEATER			FRN - 25	FRN - 25	FRS - 15	FRS - 12	FRS - 10
10 KW HEATER			FRN - 30	FRN - 30	FRS - 25	FRS - 17-1/2	FRS - 12
15 KW HEATER			FRN - 45	FRN - 45	FRS - 35	FRS - 25	FRS - 20

CONTROL CIRCUIT XFMR VOLTAGE	1/2 KVA.	1 KVA.	1-1/2 KVA.	2 KVA.
110-120	FRN - 7	FRN - 15	FRN - 17-1/2	FRN - 25
200-208	FRN - 4	FRN - 8	FRN - 12	FRN - 15
220-240	FRN - 3-1/2	FRN - 7	FRN - 10	FRN - 12
346-416	FRS - 2-8/10	FRS - 4	FRS - 6-1/4	FRS - 8
440-480	FRS - 2-1/2	FRS - 3-1/2	FRS - 5-6/10	FRS - 7
550-600	FRS - 2	FRS - 3-1/2	FRS - 4-1/2	FRS - 5-6/10
SECONDARY FUSE	FRN - 5-6/10	FRN - 12	FRN - 15	FRN - 20

CONSULT CLEAVER-BROOKS ELECTRICAL ENGINEERING DEPT. FOR "FUSETRON" FUSE SIZE FOR POWER SYSTEMS WITH VOLTAGE, FREQUENCY OR PHASE NOT MENTIONED ABOVE.

DWG. NO. 630-1253 (REVISED 12/6/88 C18-6077

[FIGURE 7-2 / RECOMMENDED MAXIMUM "FUSETRON" FUSE SIZES]

ly leveled. The piping leading to the pressure actuated controls 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. Use a burnishing tool or a hard surface paper to clean and polish the contacts. Starter contacts are plated with silver and are not harmed by discoloration and slight pitting. Replacement of the contacts is necessary only if the silver has worn thin.

CAUTION!

Do not use files or abrasive materials such as sandpaper on the contact points. It only wastes the metallic silver with which the points are covered and could cause damage to the equipment.

Thermal relay units (overloads) are of the melting-alloy type and when tripped, the alloy must be given time to resolidify before the relay can be reset. If overloads trip out repeatedly when motor current is normal, replace them with new overloads. If this condition continues, check for excessive current draw at the overloads.

The power supply to the boiler must be protected with dual element fuses (fusetrons) or circuit breakers. Similar fuses should be used in branch circuits. Standard one-shot fuses are not recommended. Information given in Fig. 7-2 is included for guidance to fuse requirements.

F. FLAME SAFEGUARD CONTROL

This microprocessor based control requires minimal maintenance because the safety and logic timings are inaccessible. There also are not any any accessible contacts. Check to see that the retaining screw is securely holding the chassis to the mounting base. Also check to see that the amplifier and the program module are tightly inserted.

The relay's self-diagnostic ability includes advising when it or its plug-in modules are at fault and require replacement.

Your spare control should be stored in a dry atmosphere and wrapped in plastic. During an extended shutdown (e.g., seasonal), the active control should be removed and stored. Moisture can cause problems with control operation.

It is recommended that service be rotated between the active and spare control to assure a working replacement is available.

!WARNING
When replacing a control, be sure to disconnect the main power supply, since the control is "hot" even though the burner switch is off. Failure to heed this warning could result in serious personal injury or death.

Make sure the connecting contacts on the control and its base are not bent out of position.

The flame detector lens should be cleaned as often as operating conditions demand. Use a soft cloth moistened with detergent to clean the lens.

A safety check procedure should be established to test the complete flame safeguard system at least once a month or more often. Tests should verify safety shutdown and a safety lock-out 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.

The following tests should be used to test the complete safeguard system. If the sequence of events is not as described, then a problem may exist. Contact your Cleaver-Brooks local authorized representative for assistance.

Checking Pilot Flame Failure

Close the gas pilot shutoff cock (Fig. 1-3). Shut off the main fuel supply. Turn the burner switch "on."

The pilot ignition circuit will be energized at the end of the pre-purge period. There should be an ignition spark but no flame. Since no flame is detected, the program relay will signal this condition. The ignition circuit will be de-energized and the control will lock out on a safety shutdown. The flame failure light (and optional alarm) will be activated. The blower motor will run through the post-purge and stop.

Turn the burner switch off. Reset the safety switch. Reopen the gas pilot shutoff cock and re-establish main fuel supply.

Checking Failure to Light Main Flame

Leave the gas pilot shutoff 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 main flame.

The fuel valve(s) will be de-energized within 4 seconds after the main burner ignition trial ends. The control will lock out on a safety shutdown. The flame failure light (and optional alarm) will be activated. The blower motor will run through the post-purge and stop.

Turn the burner switch off. Reset the safety switch. Re-establish main fuel supply.

Checking Loss of Flame

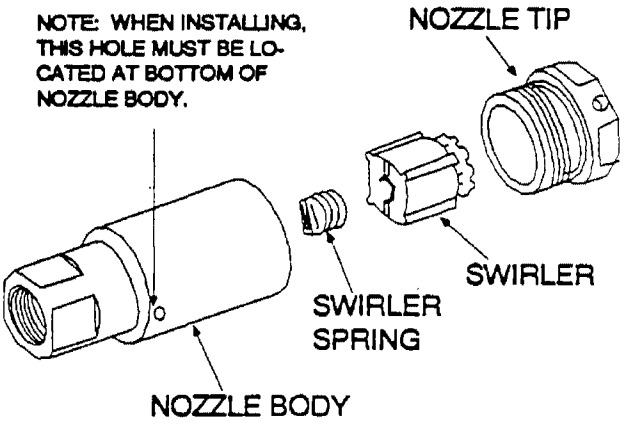
With the burner in normal operation, shut off the main burner fuel supply to extinguish main flame.

The fuel valve(s) will be de-energized and the relay will signal this condition within 4 seconds. The control will then lock out on a safety shutdown. The flame failure light (and optional alarm) will be activated. The blower motor will run through the post-purge and stop.

Turn the burner switch off. Reset the safety switch. Re-establish main fuel supply.

G. OIL BURNER MAINTENANCE

The burner should be inspected for evidence of damage due to improperly adjusted combustion. Any soot buidup on the diffuser or the oil nozzle should be removed. The setting of the oil nozzle in relation to the diffuser and other components is important for proper firing and should be checked. See Section T in Chapter 5.



[FIGURE 7-3 / EXPLODED VIEW OF STANDARD BURNER NOZZLE]

Oil Strainers

Oil strainers should be cleaned frequently to maintain a free and full flow of fuel.

Light Oil Strainers

The fuel oil strainer screen must be removed and cleaned at regular intervals. It is advisable to remove this screen each month and clean it thoroughly by immersing in solvent and blowing it dry with compressed air. To remove, loosen the cover cap screw being careful not to lose the copper gasket. If necessary, tap the strainer cover gently to loosen. Check the cover gasket for damage and replace if necessary. Slip pliers into the cross on the top of the strainer and twist counter-clockwise to remove the basket. Reassemble in reverse order.

Heavy Oil Strainers

Keep the cartridge of the oil strainer clear by regularly giving the exterior handle one complete turn in either direction. Do this often until experience indicates the cleaning frequency necessary to maintain optimum conditions of flow. If the handle turns hard, through occasional

neglect, rotate back and forth until the handle can be turned through a complete revolution. Do not force with a wrench or other tool.

Drain the sump as often as experience indicates the necessity. Remove the sump, or head and cartridge assembly for thorough cleaning and inspection at frequent intervals. Exercise care not to damage cartridge discs or cleaner blades. Wash the cartridge in solvents. Do not attempt to disassemble the cartridge.

Cleaning Oil Nozzle

The design of the burner, together with the oil purge system on a heavy oil burner, make it unnecessary to clean the oil nozzle during periods of operation. A routine check should be made during off periods or when the burner is firing on gas and any necessary cleaning performed.

If at any time the burner flame appears "stringy" or "lazy," it is possible that the nozzle tip or swirler has become partially clogged or worn. Any blockage within the tip will cause the air pressure gauge to increase above its normal value.

Disassemble with power off by unlatching and withdrawing the burner gun. Insert the nozzle body into the hanger vice and use the spanner wrench to remove the tip. Carefully remove the swirler and seating spring being careful not to drop or damage any parts. See Fig. 7-3.

Perform any necessary cleaning with a suitable solvent. Use a soft fiber brush or pointed piece of soft wood for cleaning. Do not use wire or a sharp metallic object which is apt to scratch or deform the orifices and the precision ground surfaces of the swirler and tip. Inspect for scratches or signs of wear or erosion which may make the nozzle unfit for further use. Take necessary precautions when working with solvents.

The tip and swirler are a matched set, which was precision lapped at the time of assembly. The close fit of these lapped surfaces must be maintained in order to provide optimum performance. Additional lapping may be required to provide better atomization for more efficient combustion. Do not interchange parts if a spare is kept. During reassembly, make certain that the seating spring is in place and that it is holding the swirler tightly against the tip. The swirler is stationary and does not rotate, but rather imparts a swirling motion to the oil.

See that the plugged hole is at the bottom of the nozzle body when the gun is installed (see Fig. 7-3).

Cleaning Air Purge Nozzle (No. 6 Oil) and Back Pressure Orifice Nozzle (No. 2 Oil)

The air purge nozzle and its strainer should be inspected periodically and cleaned. The nozzle consists of a tip and internal core. Clean all internal surfaces of the tip and the slotted parts of the core using a wood splinter to avoid damage from scratching. Replace the core, setting it tightly but not excessively so.

Clean the strainer screen carefully to remove any foreign matter. Use suitable solvents for cleaning. Extremely hot water at high velocity is also helpful for cleaning. Replace strainer by screwing it into the nozzle body only finger tight. Do not use an orifice of a size other than originally installed.

Ignition System

For best ignition results, maintain the proper gap and dimensions of the ignition electrode(s). Figs. 5-9 and 5-10 show the proper settings.

Inspect the electrode tip(s) for signs of pitting or combustion deposits and dress as required with a fine file. Inspect the porcelain insulator(s) for any cracks that might be present. If cracks are present, replace the electrode since cracks can lead to grounding of the ignition voltage. Since carbon is an electrical conductor, it is necessary to keep the insulating portion of electrode(s) wiped clean. Ammonia will aid in removing carbon or soot.

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

Periodically remove the access plug from the gas pilot aspirator (Fig. 5-10) and clean out any accumulated lint or foreign material.

H. GAS BURNER MAINTENANCE

The gas burner components should be inspected for evidence of damage due to improperly adjusted combustion. Combustion adjustments should be checked monthly. See Section T in Chapter 5.

Check periodically for a proper seal between the end of the burner housing and oven refractory (see Fig. 7-10). Any deterioration of the seal should be corrected, as an improper or poor seal allows air leaks, which can cause overheating or burning of the burner housing.

Whenever the burner is removed, the diffuser, gas housing and gas spuds (HTB model only) should be checked for any deterioration. Verify that the diffuser skirt conforms to the bore of the burner housing so as to minimize the amount of combustion air which bypasses the diffuser. If the burner is an HTB model, check to see that the diffuser is properly located in reference to the gas spuds. There should be 1/4" between the edge of the diffuser fins and the gas spuds when the burner is installed. Check to see that the diffuser fins do not interfere with the gas ports or gas spuds in the burner housing (see Fig. 5-11). See Section V in Chapter 5 for more information.

Check the electrode setting for any cracks that might be present on the porcelain insulator. Replace the electrode if cracking is evident, since cracks can cause grounding of ignition voltage. Inspect the tip of the electrode for signs of pitting, combustion deposits, and wear and dress as required with a fine file. See Fig. 5-10 for electrode settings.

Periodically remove the access plug from the gas pilot aspirator (Fig. 5-10) and clean out any accumulated foreign material.

Check the ignition cables for cracks in the insulation. Verify that all connections between the transformer and electrode are tight.

I. MOTORIZED GAS VALVE(S)

The motorized gas valve (hydramotor) operating mechanism is completely immersed in oil and little maintenance is required, because of the sealed design. However, proper operation should be checked on a routine periodic basis.

Keep outer parts of the valve clean, especially the stem between the operator and the valve. A nicked, scored or otherwise damaged valve stem can cause leakage. Do not remove dust covers if installed.

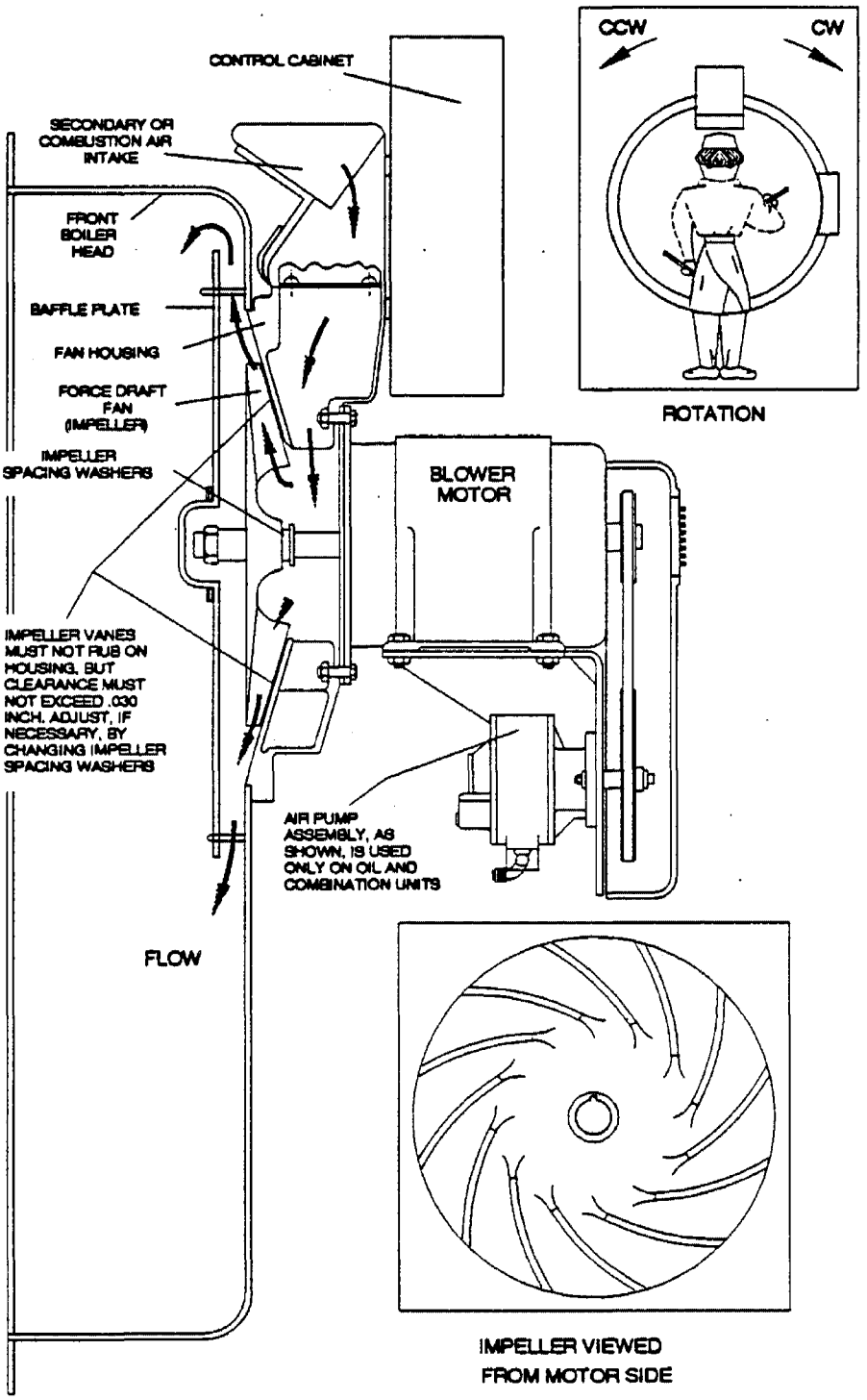
The packing gland is of the O-ring type. If oil is noticed around the operator base, or if leakage occurs, repair by replacing any leaking O-rings and refill the actuator with oil.

If the actuator is sluggish or fails to operate, even after the oil level is checked, replace the entire operator portion.

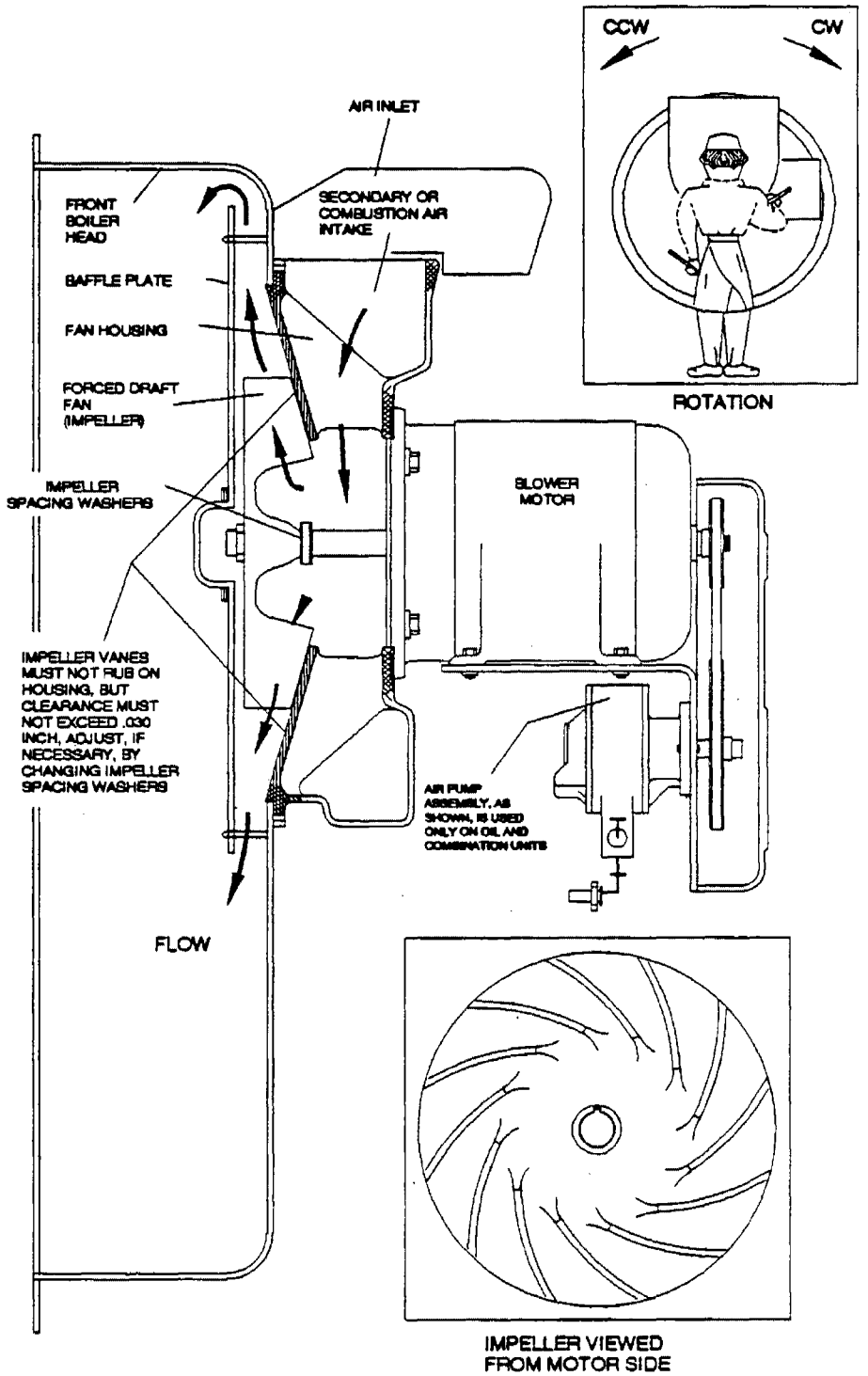
J. SOLENOID VALVES

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 removal and that reassembly is in proper order.

A low hum or buzzing will normally be audible when the coil is energized. If the valve develops a loud buzzing or a chattering noise, check for proper voltage and clean the plunger assembly and interior plunger tube thoroughly. Do not use



[FIGURE 7-4 / FORCED DRAFT FAN MOUNTING AND FLOW OF SECONDARY AIR — 100-200 HP]



[FIGURE 7-5 / FORCED DRAFT FAN MOUNTING AND FLOW OF SECONDARY AIR — 250-400 HP]

any oil. Make sure that the 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.

!WARNING
Be sure to turn off power to the valve in order to avoid electrical shock, which could result in serious personal injury or death.

Check the coil position and make sure that any insulating washers or retaining springs are reinstalled in proper order.

K. AIR CONTROL DAMPER, LINKAGE AND CAM SPRING

The burner air control damper should be checked for free movement as a part of the monthly inspection. With the burner off and the jackshaft damper control rod disconnected, the air control damper should rotate freely through its entire range of movement. Any resistance to movement or excessive play in the support bearing should be investigated and corrected before the burner is put back in operation.

The overall tightness of the linkage assembly should be checked monthly. If necessary, tighten the setscrews and the connections at the uniballs. Check the uniballs for wear and replace if necessary.

The linkage assembly should be tight but should not bind. If the linkage assembly is binding, determine the cause of the binding and correct as necessary.

Linkage rod end attachment points should be marked on the variable displacement linkage arms as an aid in subsequent reassembly.

Inspection of the air damper and linkage bearings should be performed on a more frequent basis if the boiler is operating in a dirty environment.

The fuel cam profile spring should be inspected monthly for wear, scoring or distortion. If any of these conditions are found, the cam or cam spring must be replaced immediately to avoid the possibility of breakage in service. Use care to avoid damaging the cam or spring during installation.

Lubricate the cam spring occasionally with a non-gumming, dripless, high-temperature lubricant such as graphite or a silicone derivative.

CAUTION!
Combustion should be checked and readjusted as required whenever the burner is removed or any control linkage is disturbed in order to avoid damage to the equipment.

L. FORCED DRAFT FAN

Figures 7-4 and 7-5 show the flow of secondary, or combustion air through the intake opening, connecting the duct housing and impeller.

The position of the impeller vanes with relation to the air intake housing is extremely important to the output capacity of the fan. The impeller vanes should not rub or contact the air housing but at the same time the clearance must not be more than .030 inch and preferably less.

The inset at lower right of figures 7-4 and 7-5 is a view of the impeller from the motor side indicating the direction of the rotation.

The inset at the upper right shows a designation of "clockwise" and "counter-clockwise" as the terms are used throughout this manual.

Check occasionally to see that the fan is securely tightened to the motor shaft. If the boiler is installed in a dusty location, check the vanes for

deposits of dust or dirt since these buildups can cause a decrease in air capacity or lead to an unbalanced condition.

CAUTION!

If the boiler is installed in a dusty location, check the vanes occasionally for deposits of dust or dirt. These buildups can cause a decrease in air capacity, lead to an unbalanced condition, or cause damage to the equipment.

M. SAFETY VALVES

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

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 because 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. Allow the valve 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 to 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 worn and cause it not to seal properly. This will cause the valve to leak and necessitate down-time of the boiler for valve repair or replacement. Repair of a valve must be done only by the manufacturer or its 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.

N. FUEL OIL METERING VALVE, ADJUSTING AND RELIEF VALVES

In the event that a leak occurs in the packing of the metering valve, the packing nut should be snugged gradually to stop the leak.

CAUTION!

Excessive tightening of metering valve packing nut prevents free movement of the metering stem and can cause damage to the equipment.

If replacement of the metering valve packing is necessary, procure P/N 880-370 kit and install in accordance with the following procedure.

(1) Shut off the oil flow. Be sure no pressure shows on the gauge.

(2) Match mark the cam hub and drive shaft. This will enable replacement of the cam in the original position and result in a minimum of cam adjustment when the burner is refired.

(3) Clamp or hold the metering stem in the down position.

(4) Loosen the setscrews in the cam hub and rotate or move the cam to a position where it does not interfere with the stem removal.

(5) Withdraw the metering valve stem and spring. Do not drop or mishandle. Check for nicks or scratches. Check that the pin holding the metering portion is not protruding. Back off the packing gland.

(6) Remove the capscrews holding the jack shaft support bracket so that the bracket can be moved. It may be necessary to also loosen the supporting bracket on the far end of the shaft.

(7) Remove the existing packing rings and guides. Do not reuse these.

(8) Lightly coat the stem with the lubricant provided with the packing kit. Place the new packing, O-rings and guides onto the stem in the sequence shown in Fig. 7-5. The beveled face of the guides and the teflon rings must face upward, with the exception of the upper brass guide which is faced down. Make sure that the O-rings are properly located.

(9) Using the stem as a guide, insert the assembled packing into the cavity; then withdraw the stem.

(10) In the event the packing is too high, remove one teflon packing from each side of the middle brass guide as needed. Under no circumstances eliminate the two teflon packings on only one side of the brass guide.

(11) Replace the gasket, put the support in place, and secure all fastenings.

(12) Replace the metering stem and spring. Lightly lubricate the stem to facilitate insertion and easy movement. Use care when inserting so that the orifice and the stem are not damaged.

(13) Snug the packing gland, but only sufficiently to place slight tension on the packing. The stem must move freely from the force of the spring.

(14) Work the stem up and down several times to insure that it moves freely.

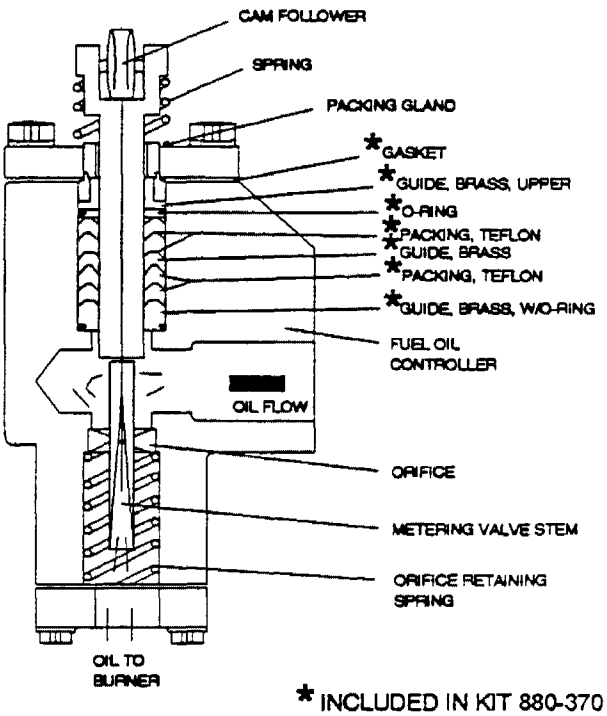
(15) Depress the valve stem and replace the cam. Mate the match marks and secure the setscrews. Make sure the cam spring is centered in the roller.

(16) Restore the oil flow. Test fire the burner at various firing rates making certain that the metering stem freely follows the cam.

(17) Tighten the packing gland after a period of operation, if required, to maintain proper tension on the packing. Do not overtighten.

If there are indications that the oil metering valve has become clogged at its orifice, it will be necessary to disassemble the control to remove the obstruction. Clean the slotted stem of the oil metering valve with suitable solvent and blow-dry with an air line. Follow the procedure outlined above when removing or reinstalling the metering valve stem. Also check all fuel line strainers.

Should a pressure adjusting or relief valve become clogged, disassemble by releasing the locknut and backing off the adjusting screw to relieve tension on the diaphragm. Remove valve cover and diaphragm. This will expose any dirt or foreign material which may have entered the valves. Clean out carefully and reassemble. It is recommended that the diaphragms be replaced annually.



* INCLUDED IN KIT 880-370

[FIGURE 7-6 / METERING VALVE PACKING SEQUENCE]

O. THE AIR PUMP AND LUBRICATING SYSTEM

Air Pump

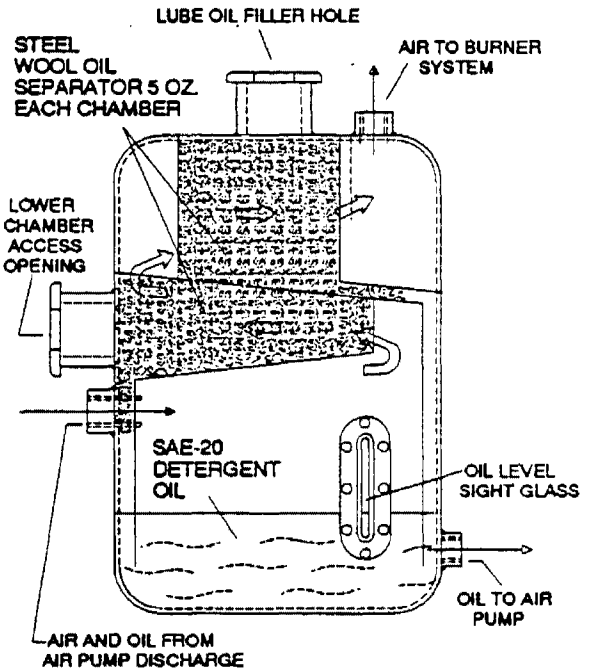
The air pump itself requires little maintenance; however, the life of the pump is dependent upon a sufficient supply of clean cool lubricating oil. The oil level in the air-oil tank must be observed closely. Lack of oil will damage the pump making replacement necessary. Disassembly or field repairs to the pump are not recommended.

Lubricationg Oil

Lubricating oil must be visible in the gauge glass at all times. There is no specific level required as long as oil is visible. Do not operate if oil is not visible.

Oil with proper viscosity must be used. SAE20 detergent is recommended although SAE10 detergent also is permissible.

Oil is normally added by removing the filler cap plug in the top of the tank (Figure 7-5) and adding sufficient oil to raise the level to the midpoint of the sight glass. This cannot be done while the



[FIGURE 7-7 / AIR OIL RECEIVER TANK]

boiler is in operation. If absolutely necessary to add oil during operation, remove the air cleaner and slowly add clean oil into this opening.

CAUTION!

Oil must NEVER be added unless the pump is in operation and the strainer screen in place in order to avoid damage to the equipment.

The oil and its container should be clean. Although there is a strainer in the lube oil line, its purpose is to remove any unwanted materials rather than to act as a filter for unclean oil.

Air Cleaner

Never operate the air pump without the air cleaner in place. The cleaner itself must be periodically checked and its element flushed and cleaned. The correct level of oil must be maintained in the cleaner.

Air-Oil Tank

The air-oil tank contains steel wool used as a filtering medium to separate the lube oil from the compressed air. A typical tank is show in figure 7-5. The wool is packed into two compartments each containing approximately five ounces. The wool should be replaced periodically whenever inspection reveals the need. Careful packing is necessary to assure even density. Do not over compress the wool and be sure it is fluffed out to fill all available space. Improper packing can cause high oil consumption. Use wool of proper density — refer to the parts list in Chapter 8.

Should sludge accumulate in the tank, drain it and flush with a suitable solvent.

Lube Oil Cooling Coil

The fins on the tubing must be kept clean and free of any dust or dirt that would impede air flow and cause overheating. Use an air hose to blow away debris. Internal cleaning of the tubes is seldom required if a good quality lube oil is used.

Lube Oil Strainer

The lube oil strainer screen must be removed and cleaned at regular intervals. It is advisable to remove this screen each month and clean thoroughly by immersing in solvent and blowing dry with compressed air. To remove, loosen the cover cap screw, being careful not to lose the copper gasket. Tap the strainer cover gently to loosen. Check the cover gasket. Slip the pliers into the cross on the top of the strainer and twist counterclockwise to remove the gasket. Re-assemble the strainer in reverse order.

General

Keep the motor and other components free from dust and dirt to prevent overheating and damage.

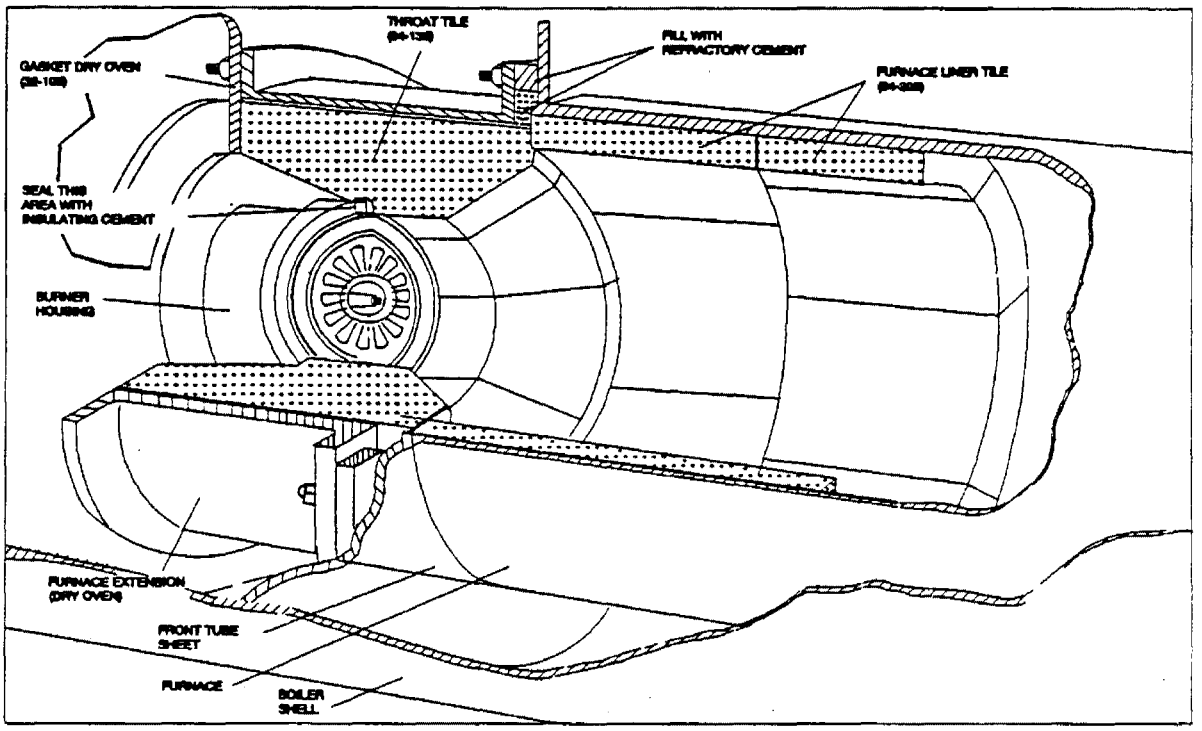
P. REFRACTORY

The Cleaver-Brooks boiler is shipped with completely installed refractory. This consists of the rear head (Figure 7-6), the inner door and the furnace liner (Figure 7-7). Normal maintenance requires little time and expense and prolongs the operating life of the refractory. Preventive maintenance through periodic inspection will keep the operator informed of the condition of the refractory and will guard against unexpected and unwanted down time and major repairs.

Frequent wash-coating of refractory surfaces is recommended. High temperature bonding air-dry type mortar, dilluted with water to the consistency of light cream, is used for this purpose. Re-coating intervals will vary with operating loads and are best determined by the operator when the heads are opened for inspection.

Furnace Liner

Maintenance consists of an occasional wash coating of the entire liner. Face all joints or cracks by applying high temperature bonding mortar with a trowel or fingertips. This should be done as soon as cracks are detected.



[FIGURE 7-8 / FURNACE LINER REFRACTORY — 100-200 HP WITH SEAL]

Should segments of the liner burn away or fall out, replace the entire refractory. Any refractory that may break out should be removed as soon as detected so that it will not fuse to the bottom of the furnace and obstruct the flame.

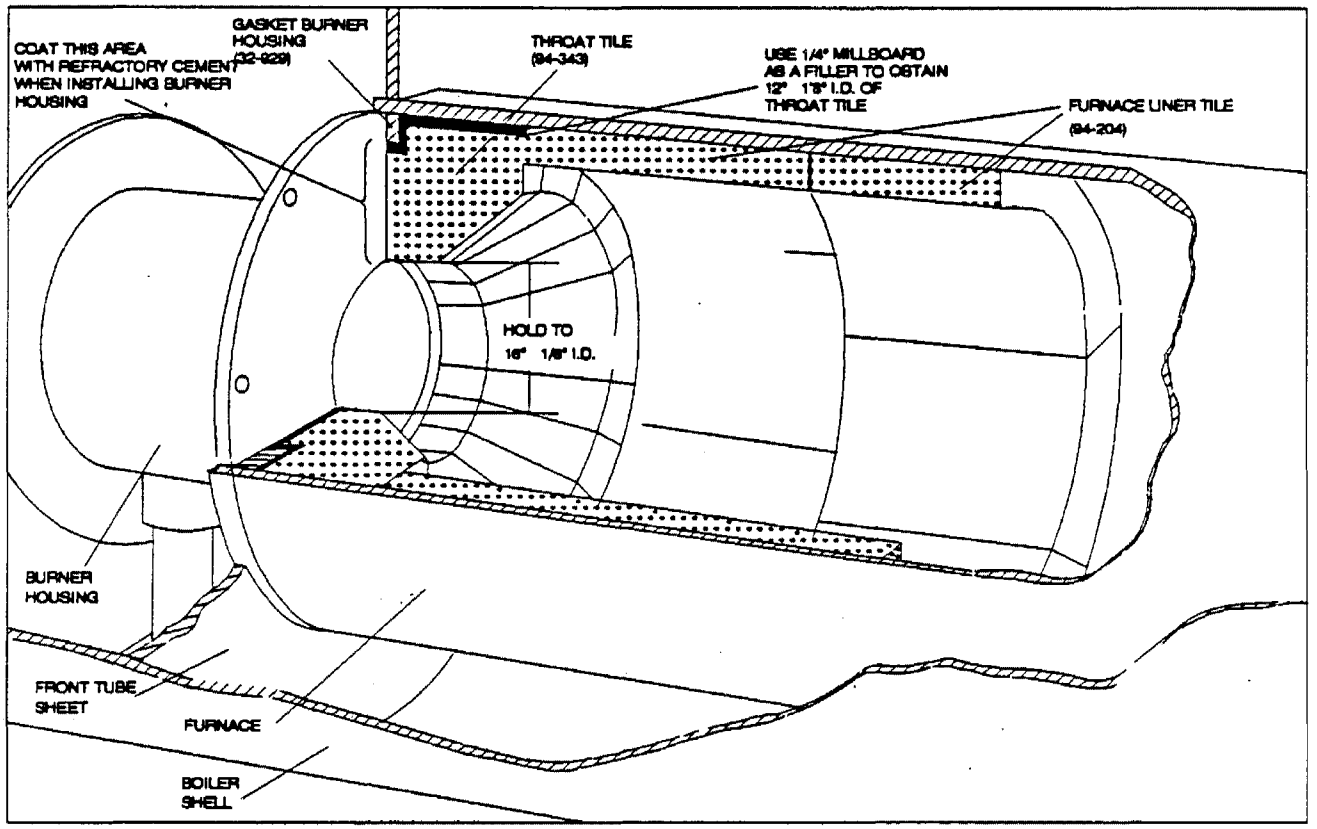
If replacement is necessary, refer to Chapter 8 and order proper replacement materials. Remove existing refractory. Thoroughly clean the furnace to remove all old refractory cement or other foreign material to ensure that the new liner seats firmly against the steel. Inspect furnace metal.

Depending upon the design pressure of the boiler, the furnace may be of the corrugated type. It is necessary to fill in the corrugation valleys under the furnace liner tile from 4 o'clock to 8 o'clock with insulating cement. The liner tile should be fitted tightly against the crown of the corrugations.

Throat Tile and Liner Installation

The furnace lining is shown in Figs. 7-8 and 7-9. The throat tile must be installed to maintain an approximately 16" inside diameter and be centered in the furnace. Since the thickness of the furnace metal varies with the boiler design pressure, a shim of appropriate thickness must be used to compensate for this variance. A layer or two of insulating board, or a bed of refractory material, may be used to center the ring. The liner tile can be fitted tightly against the furnace since the finished diameter is not critical.

It is recommended that the tile be dry fitted, match marked, removed, and then reinstalled with the proper amount of refractory cement. Thin joints are desirable. Generally, it will be necessary to shave a portion from one or more tile to obtain a fit. If a fill piece is required, cut it to fit and install this piece at the bottom of the furnace.



[FIGURE 7-9 / FURNACE LINER REFRACTORY — 250-400 HP WITHOUT SEAL]

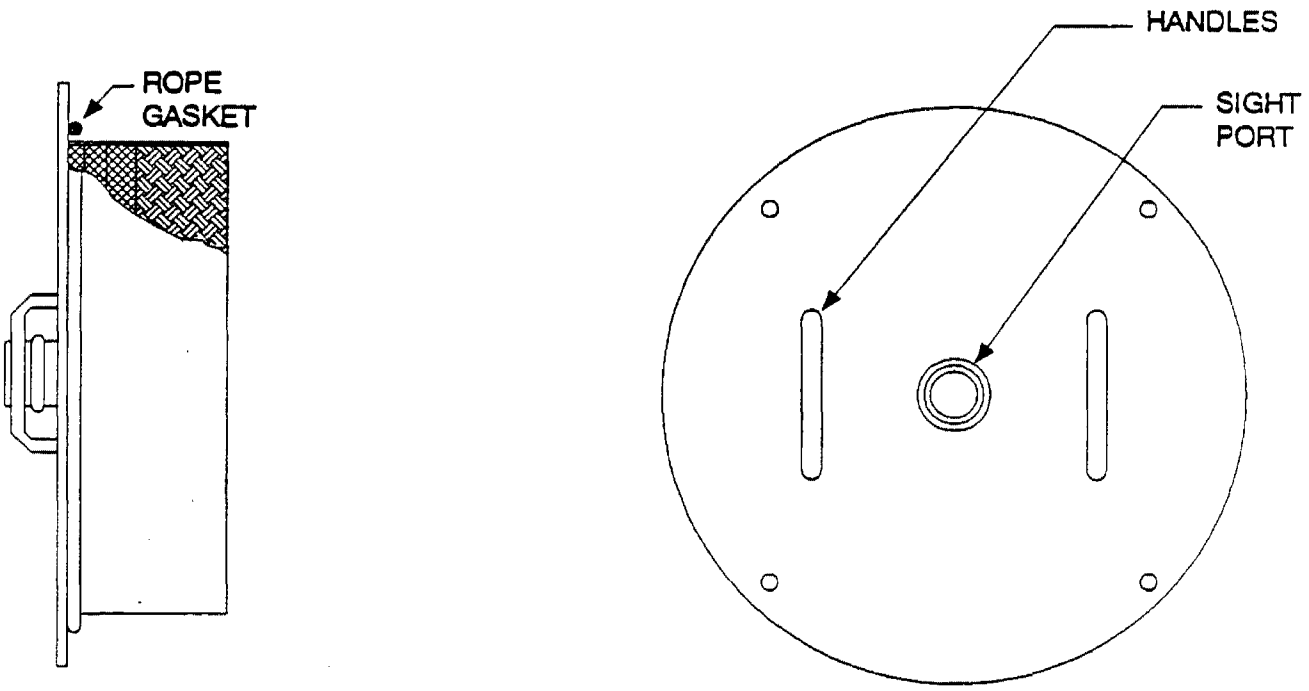
CAUTION

The area between the burner housing and the throat tile requires a good seal. An improper or poor seal allows air leaks that can cause overheating and burning of the burner housing metal. This area should be inspected semi-annually and repaired or replaced as necessary in order to avoid damage to the equipment.

When installing the housing, or the tile against the housing, liberally coat this surface with refractory cement. Remove any excess cement that is squeezed out.

Allow the refractory to air dry as long as possible. If immediate use is required, fire intermittently at low rate for several hours to thoroughly dry the refractory.

NOTE: For detailed information, request Bulletin C10-5921 or for replacement, contact your local Cleaver-Brooks authorized Representative.



[FIGURE 7-10 / REAR ACCESS PLUG]

Rear Access Plug
This plug seals the access crawlway to the combustion chamber into which combustion gases exit from the furnace tube before entering the second pass tubes.

The refractory face of the plug should be inspected for deterioration when the boiler is opened for inspection.

After removing the rear access plug, clean the crawlway flange with a scraper or wire brush. Inspect the plug sealing gasket and replace it if damaged.

Front Inner Door

The front inner door is lined with a lightweight castable insulation material. Thin "hairline" cracks may develop after a period of time. However, these will generally tend to close due to expansion when the boiler is fired.

A thin wash-coat mixture applied gently with a brush is helpful in maintaining a hard surface.

Minor repairs can be accomplished by enlarging or cutting out affected areas, making certain that they are clean and then patching as required. Should the entire installation require replacement, remove existing material and clean to bare metal. Inspect the retaining pins and replace if necessary. Reinforcing wire suitably attached may also be used. The recommended insulation is known as Vee Block Mix and is available in 50 lb. bags (CB P/N 872-162).

Mix the material with water to a troweling consistency. Mixing should be completely uniform with no portion either wetter or drier than another. Trowel this mixture into any areas that are being patched. If replacing complete insulation, begin at the bottom of the door and apply the mixture to a thickness equal to the protecting shroud. With a trowel, apply horizontally back and forth across the door in layers until the required thickness is reached.

Allow to air-dry as long as possible. If immediate use of boiler is required, fire intermittently at low fire to avoid rapid drying of the material.

Rear Door

The rear door seals the chamber into which combustion gases flow after exiting the third pass and from which the gases are exhausted through the vent opening.

The rear door is insulated with a cerawool material which is stabilized with a ceramic rigidizer.

When the door is open for annual inspection, reapply the rigidizer to maintain a durable surface.

Q. OPENING AND CLOSING DOORS

Opening Front or Rear Door

!WARNING
Before loosening the door bolts, tighten the nut on the davit arm stud to support the door and avoid the possibility of serious personal injury or death.

This will prevent sagging and facilitate opening of the door.

CAUTION
Do not open a boiler when the boiler is hot. Rapid cooling by exposure to ambient air temperature may cause damage to the refractory or to the boiler itself.

After opening either door, support the open door with blocks or a jack and check the gaskets and sealing surfaces. If the door gaskets are hard or brittle, they should be replaced. The sealing surfaces of the door and tube sheet should be clean. Make sure that all gasket retaining fasteners are in place.

Closing and Sealing Doors

Coat the door gasket with an oil and graphite mixture. Swing the door to the closed position and run all of the retaining bolts in until snug. Tighten the bolts evenly, starting at the top center and alternating between the top and bottom bolts until both are tight. Do not overtighten. Tighten alternate bolts until all are secure and the door is gas tight.

CAUTION
After closing the door, loosen the nut on the davit arm stud to release tension on the davit arm. Failure to do so may result in damage to the boiler due to thermal stresses during boiler operation.

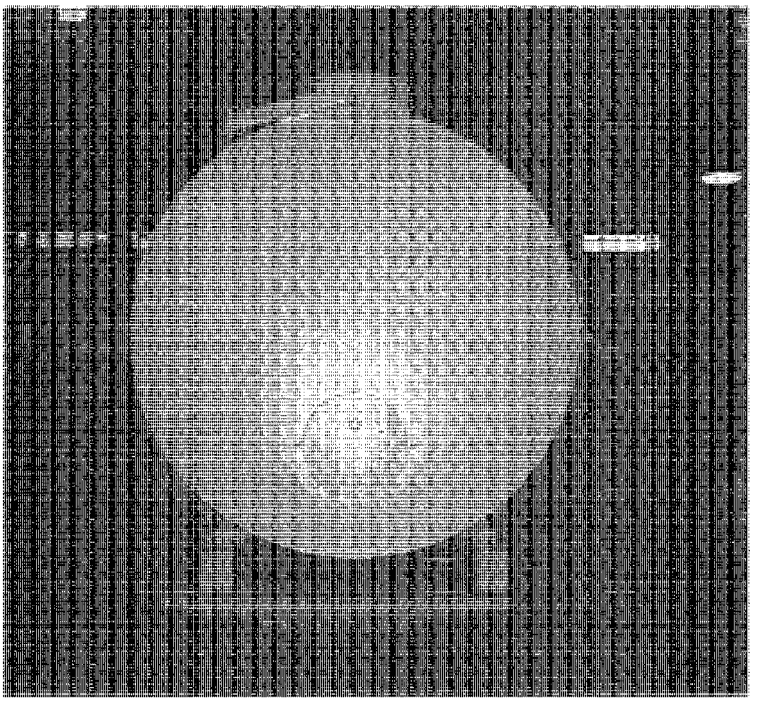
After the boiler is back in operation, retighten the door bolts to compensate for compression of the gasket or movement of the door.

R. 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 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.



[FIGURE 7-11 / REAR DOOR]

Complete renewal of grease, when necessary, can be accomplished by forcing out the old grease with the new grease. 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	1B + RB No. 2
Fiske Bros.	Ball Bearing Lubricant
Standard/Mobil	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 off any excess. Repeat application at required intervals to maintain freedom of motion of parts.

Solenoid and Motorized Valves

Solenoid valves and motorized valves require no lubrication.

S. OIL HEATERS – ELECTRIC, STEAM, HOT WATER

An annual maintenance of these heaters consists of removing the heating element from the shell and scraping any accumulation of carbonized oil or sludge deposits that may have collected on the heat exchanging surfaces.

Before breaking any of the electrical connections to the electric heating elements, mark all wires and terminals to assure rapid and correct replacement of wires.

Finish the cleaning process with a cleaning solvent to cut all hardened deposits from the heater element. Because of the insulating effect of carbon and sludge, periodic cleaning is necessary to prevent overheating of the elements. If operation of the heater becomes sluggish, examine the elements at once and clean as required.

Inspect the shell or tank each time the heater is removed. Flush all accumulated sludge and sediment from the tank before reinstalling the heater.

The condensate from steam oil heaters must be safely discharged to waste. This waste should be checked periodically for any traces of oil which would indicate leaking tubes within the heater.

The hot water oil heater (Fig. 7-14) contains a heat transfer solution. Oil flows through an inner tube while boiler water surrounds the outer tube. The space between the two tubes is filled with the heat transfer solution and is connected to an expansion chamber on the rear of the heater. A visual indicator on this chamber reveals the presence of any oil if an oil leak occurs.

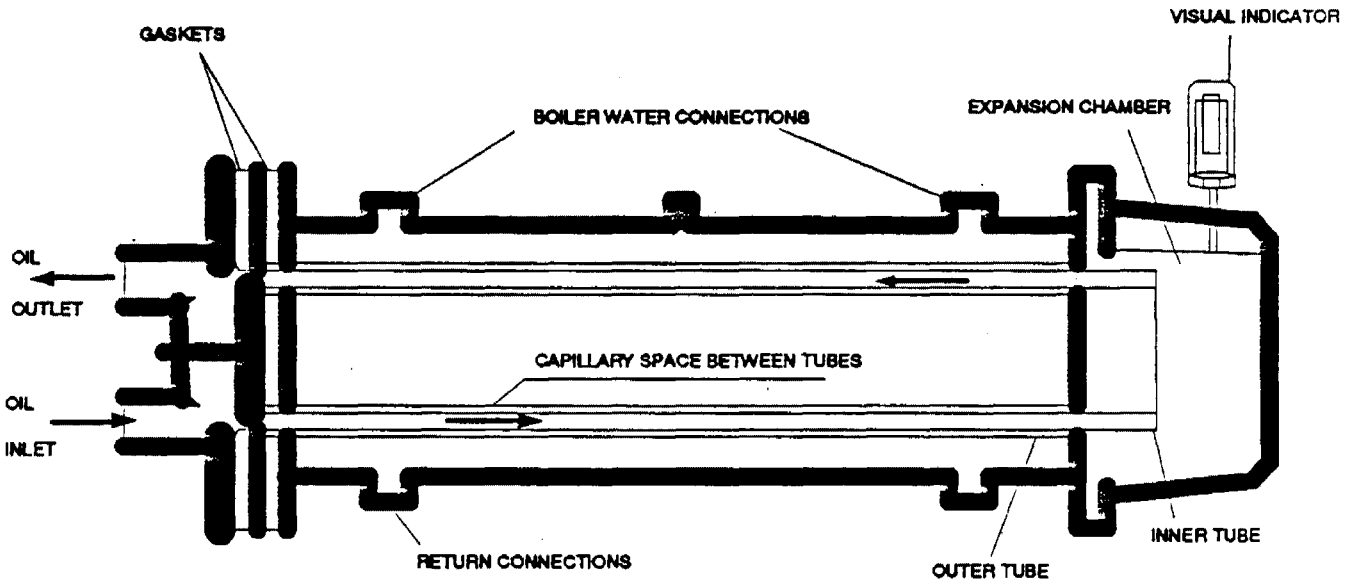
A 50/50 solution of permanent anti-freeze and water is generally used as the heat transfer solution. If there is no danger of freezing, plain water may be used as a replenishment if necessary to refill.

Evidence of oil in either the steam heater condensate or in the water heater indicator demands prompt repair.

T. COMBUSTION

The frequency of burner adjustments depends upon several factors, including; type of burner, type of fuel, load conditions, ambient temperature, climatic variables, and general maintenance practices.

The air-fuel ratio should be checked monthly since this will alert the operator to losses in efficiency, which do not produce visible flame change. Any time maintenance is performed on the burner linkage the the air-fuel ratio should be checked. Readjustment of the burner may be required due to variations in fuel composition. A combustion analyzer should be used to adjust air-fuel ratio for maximum operating efficiency. If your burner requires adjustments, contact your Cleaver-Brooks local authorized representative for assistance.



[FIGURE 7-12/ CIRCUIT LAYOUT OF HOT WATER OIL HEATER (ALSTROM)]

Recommended Boiler Inspection Schedule

Daily	Weekly	Monthly	Semi-Annually	Annually
Check water level	Check for tight closing of fuel valve	Inspect burner	Clean low water cutoff	Clean fireside surfaces
Blowdown boiler	Check fuel and air linkage	Analyze combustion	Remove and clean oil preheater	Clean breeching
Blowdown water column	Check indicating lights and alarms	Check cams	Inspect refractory	Inspect waterside surfaces
Check combustion visually	Check operating and limit controls	Inspect for flue gas leakage	Clean oil pump strainer, filter	
Treat water according to the established program	Check safety and interlock controls	Inspect for hot spots	Clean air cleaner and air/oil separator	
Record feedwater pressure/temperature	Check for leaks, noise, vibration, unusual conditions, etc.	Check for tight closing of fuel valve	Check air pump coupling alignment	
Record flue gas temperature		Check fuel and air linkage		
Record oil pressure and temperature		Check indicating lights and alarms		
Record gas pressure		Check operating and limit controls		
Record atomizing air pressure		Check safety and interlock controls		
Record boiler water supply and return temperatures		Check for leaks, noise, vibration, unusual conditions, etc.		
Record makeup water usage				

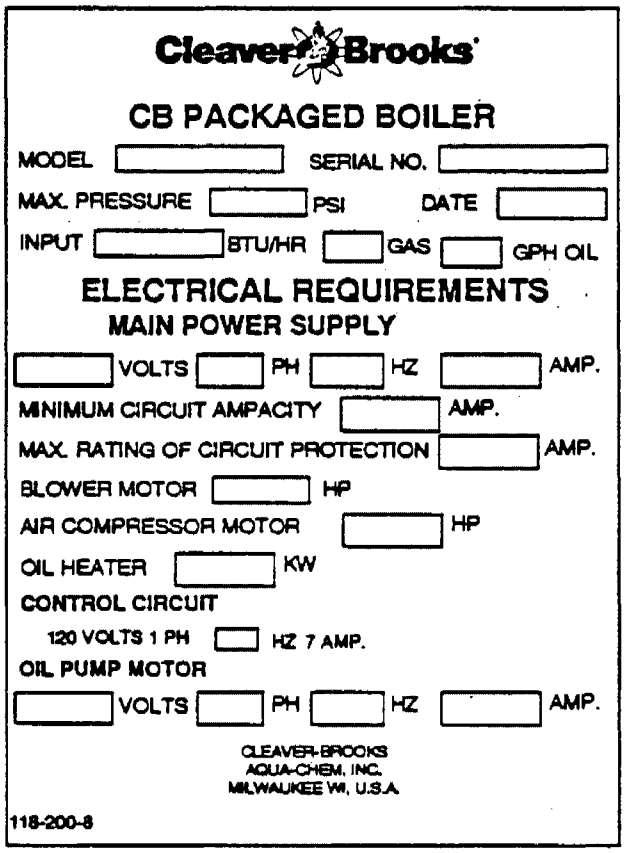
[FIGURE 7-13 / RECOMMENDED BOILER INSPECTION SCHEDULE]

CHAPTER 8

PARTS ORDER/LIST INSTRUCTIONS

FURNISH COMPLETE INFORMATION WHEN ORDERING PARTS — When ordering parts for repair or spares, give description and state quantity of parts desired, together with the complete nameplate data, including rating, model, and serial number of the motor and all data.

WHERE TO ORDER PARTS. Repair or replacement parts should be ordered from your local Cleaver-Brooks authorized Representative.



Contact your local Cleaver-Brooks Representative for prompt supply of replacement parts.