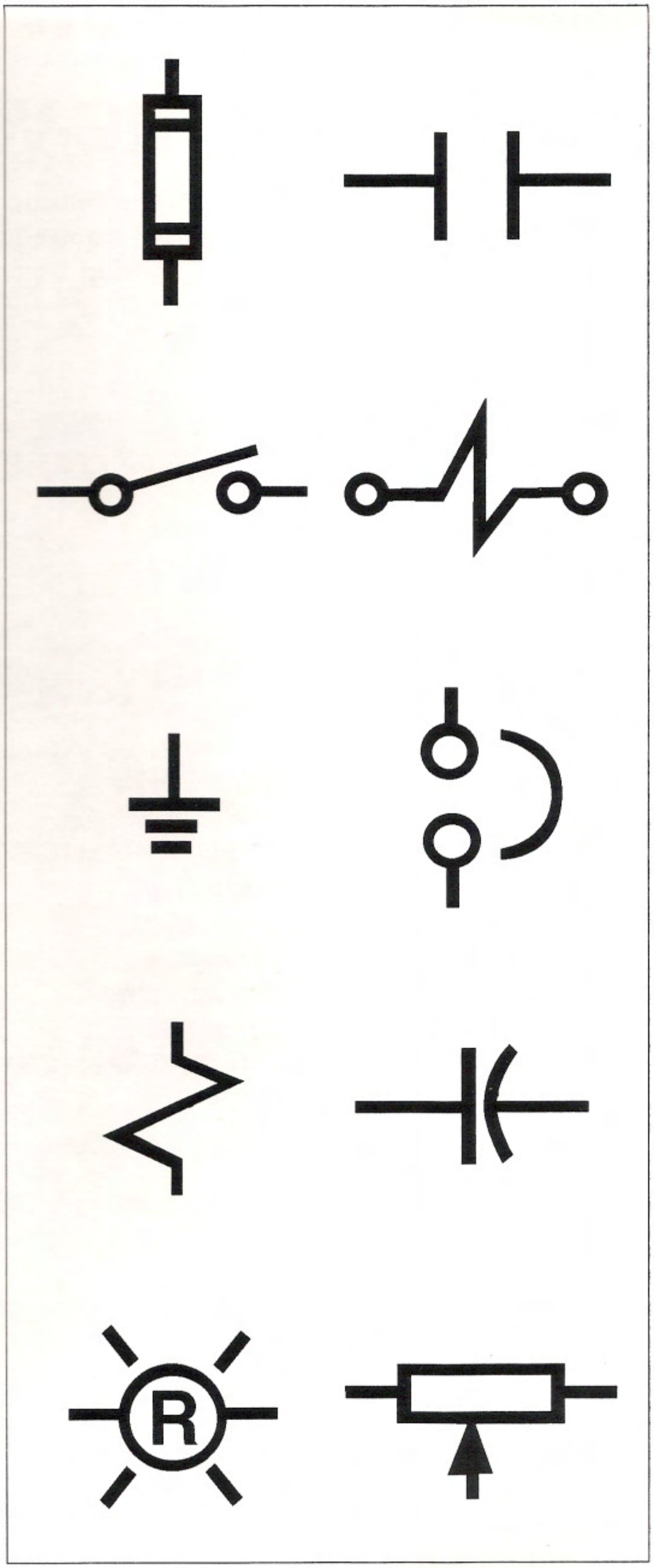
HOW TO READ
Schematic Wiring Diagrams



Cleaver Brooks®

DIVISION OF AQUA-CHEM, INC.
MILWAUKEE, WISCONSIN, U.S.A.

Return to
Table of Contents

HOW TO READ SCHEMATIC WIRING DIAGRAMS

Cleaver-Brooks uses the schematic wiring diagram to represent the wiring of the various electrical components required on package boilers. This book is a guide to the interpretation of these wiring diagrams.

TABLE OF CONTENTS

SYMBOL DEFINITIONS

Standard electrical symbols developed by the electrical industry are documented in the American Standards Association (ASA) publications. Some of the more common electrical devices (and symbols) used on boiler wiring diagrams are shown below:


SWITCH: A device used to open or close an electrical circuit; when no appendage is shown, it is manually operated.

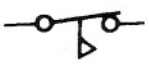

LIMIT SWITCH: A switch that is mechanically actuated.


PRESSURE CONTROL: A switch actuated by steam, water, air, oil or gas pressure. This symbol may also be used for a vacuum control.


TEMPERATURE CONTROL: A switch actuated by steam, water, air, oil or gas; a sensing bulb is located in or near the controlling fluid.

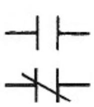

LEVEL CONTROL: A switch actuated by liquid level; a float is located in the liquid.

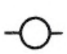

TIME DELAY SWITCH: A switch actuated by a mechanical or pneumatic timing device.

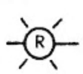

FLOW SWITCH: A switch actuated by steam, water, air, oil or gas flow.


CIRCUIT BREAKER: A manually operated device designed to open automatically when current through it is excessive.


PUSH BUTTON: A manually operated switch which returns to position shown when actuating force is released. Top symbol is "normally open," bottom symbol is "normally closed."


CONTACT: A switch actuated through the energization of another electrical circuit. Top symbol is "normally open," bottom symbol is "normally closed."

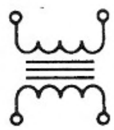

GENERAL SYMBOL for relay coils, starter coils, motorized valves, scanners, alarms, meters, etc. This device must be identified as to function.



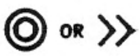
PILOT LIGHT: A visual annunciator to indicate power to a specific circuit; the function must be defined. The letter in the center indicates lens or lamp color.


SOLENOID: A device that produces linear mechanical motion when energized; usually used to represent solenoid-actuated valves.


FUSE: A device that breaks an electrical circuit when current flow is excessive by melting current carrying element. This device may be used to provide "branch circuit overcurrent protection."


TRANSFORMER: A device that is used to increase or decrease (step up or step down) a voltage to the desired value, or to isolate circuits.


GROUND: An electrical connection made to earth, or ground, in accordance with the National Electrical Code rules for grounding.



SEPARABLE CONNECTOR: Electrical wiring constructed to be readily separated, such as a plug and socket combination.

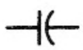

THERMAL OVERLOAD: A device that breaks an electrical circuit when current flow is excessive by heating a tripping device.


MAGNETIC OVERLOAD: A device that breaks an electrical circuit when current flow is excessive by mechanical action on a tripping device.


TERMINAL BLOCK: Wire connectors arranged in a row for the convenience of making electrical connections.

MOTOR: A device to convert electrical energy to rotary mechanical energy. Leads are designated at T1, T2, etc., as necessary, for various types of motors; a three phase motor is shown.


POTENTIOMETER: A device used to vary voltage and/or current for control purposes by varying the resistance in the circuit.


CAPACITOR: A device used to: (a) momentarily store electrical energy, (b) to provide spark suppression, (c) to provide proper starting torques on electrical motors, or (d) as applied to power lines, for power factor correction. Formerly called a condenser.

SWITCH POSITIONS

Switch position is significant for proper interpretation. The following chart is presented to illustrate the meaning of switch position. The designations "normally open" and "normally closed" refer to the switch position when no force or power is applied to the actuating mechanism.

This chart applies only to momentary or spring-return devices. Maintained-position toggle switches, disconnects, selector switches, etc., will be shown in an appropriate position.

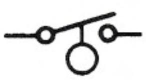
In viewing switch positions, the actuating force is considered to be upward. Exception: push buttons are viewed with an assumed downward actuating force. Typical examples of switch positions are shown below.

Normally Open (N.O.)	Normally Closed (N.C.)
	
 (held closed)	 (held open)

High water alarm or limit circuit, boiler empty (N.O. liquid level switch)

High water alarm or limit circuit, boiler filled (N.O. liquid level switch, held closed)

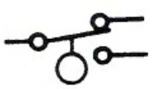
Pump ON or low water alarm circuit, boiler empty (N.C. liquid level switch)



Pump OFF or low water alarm circuit, boiler filled (N.C. liquid level switch, held open)

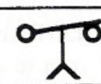
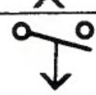
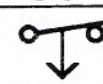
Limit circuit, pressure below the set point (N.C. pressure switch)

Limit circuit pressure above set point (N.C. pressure switch, held open)

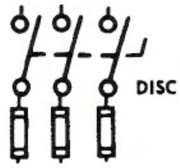


If three wire devices are used they may be shown as: Top contact, limit circuit; bottom contact, alarm circuit; boiler filled. (Top contact is N.O. held closed, bottom contact is N.C. held open.) Upon drop in level, top switch opens, bottom switch closes, this opens limit circuit and closes alarm circuit.

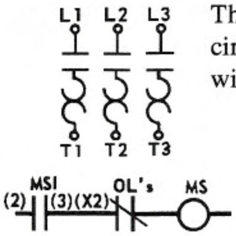
Time delay contacts have tails which show action. The top group would refer to pre-purge or scavenger timers, the bottom group to post-purge timers. Refer to the table below.

	Normally open	Normally closed
Delay when energized		
Delay when de-energized		

Symbols are often combined to show a complete device. Some of the more common devices are shown below.



Three-pole, fusible, disconnect switch.

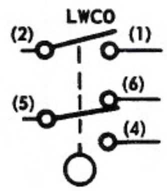


Three-pole magnetic motor starter (power circuit wiring is shown in top portion; control wiring is shown in bottom portion).

Modulating Pressure Control. Potentiometer actuated by pressure sensitive mechanism.

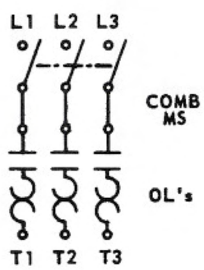
Modulating Temperature Control. Potentiometer actuated by temperature sensitive device.

Control Relay with one "normally open" and two "normally closed" contacts.

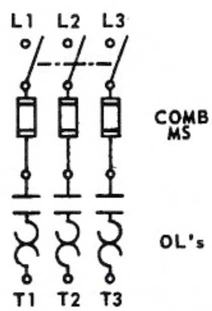


Low Water Cut-off and Pump Control. Shown with boiler water at proper level (limit circuit is held closed, and alarm circuit is held open in bottom stage; pump control circuit is held open in top stage). Device terminal designations are indicated in parentheses.

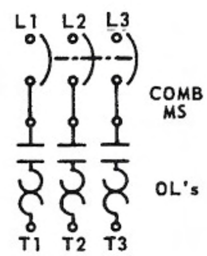
COMBINATION STARTERS



(MAGNETIC STARTER with non-fused disconnect)



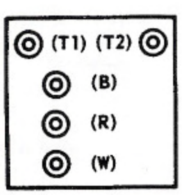
(MAGNETIC STARTER with fused disconnect)



(MAGNETIC STARTER with circuit breaker)

COMPLEX DEVICES

Terminal connections only are shown for complex devices. If shown in their entirety, they would unduly complicate the schematic diagram. If further details are required, consult manufacturer's literature.



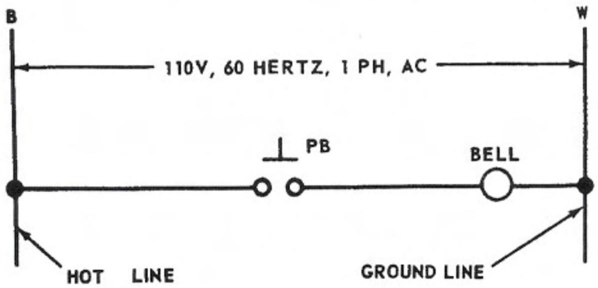
Modulating Damper Motor (M-H 900 Series). Terminal designations only are shown.

Program Relay or Combustion Safeguard Terminals. Number or letter designations on device are shown within the symbol. Operating sequence chart is sometimes provided as an aid in reading diagram.

SIMPLE CIRCUITS

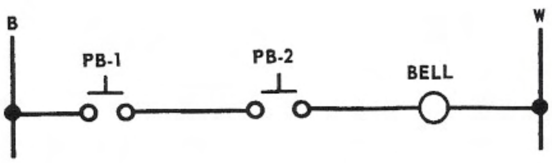
The development of schematic diagrams is based on certain fundamentals. A power supply is necessary to provide the electrical energy for the control system. The grounded side of the power supply (white wire) is shown as a vertical line on the right side of the diagram. All inductive components (that is, coils, transformers, lights, solenoids, etc.) are connected to it. The hot side of the power supply (black wire) is shown as a vertical line on the left side of the drawing. All inductive components are connected to it via proper switches and contacts so that the devices will function in the order intended.

A simple door bell circuit is shown below.

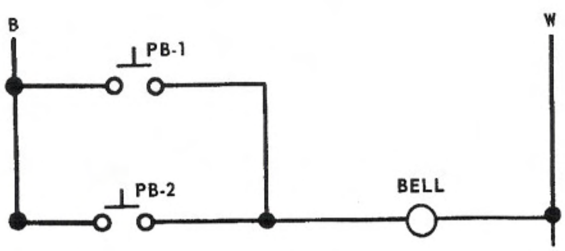


When the push button (PB) is depressed, current flows from the "hot" line through the PB contacts to the bell and then to the "ground" line. When the button is released, the bell stops ringing because current flow has been interrupted by the opening of the PB contacts (through action of an internal spring).

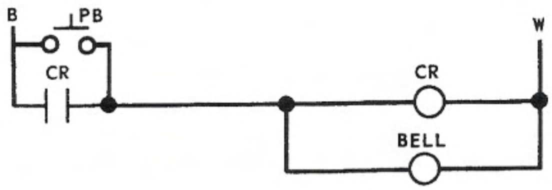
A more complex circuit, requiring that two push buttons be depressed SIMULTANEOUSLY to ring the bell, is shown next.



If it is desired that EITHER push button should ring the bell, the circuit would be shown as follows:

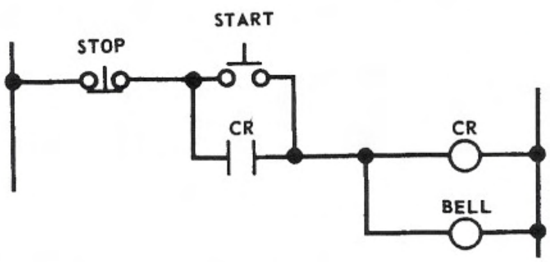


A simple "holding" circuit can be shown this way.



In this circuit, the bell will start to ring when the PB is depressed and will continue to ring when the button is released. The reason is that the control relay (CR) is also energized when PB is depressed. The N.O. contact of CR closes and "holds" the CR; that is, the holding coil of relay CR remains energized via the N.O. contact of CR, which is now closed. Because the bell is wired in parallel with the coil of CR, it is also continuously energized. In the above circuit, the alarm bell and CR can not be de-energized unless the power supply to the control circuit is interrupted.

In general, a "stop" push button is incorporated in the circuit to allow de-energization of the bell and CR without interrupting the entire control circuit power supply.

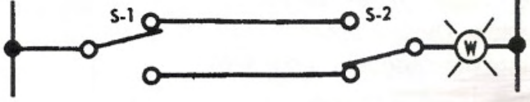


To cause the bell to ring, press the "start" PB; to make it stop ringing, press the "stop" PB. This is a "fail safe" circuit because the bell can not ring if the "stop" and "start" PBs are pressed simultaneously. Momentary or sustained loss of control circuit power will also cause the bell to stop ringing if the bell circuit was energized.

A few more simple circuits using toggle switches instead of push buttons will be illustrated next.

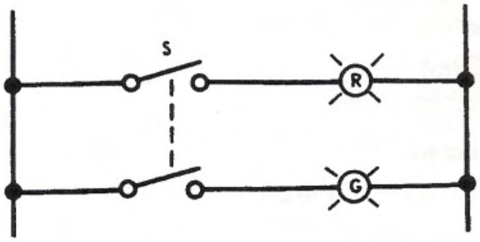
This circuit is employed to light this lamp from either one of two locations using a maintained contact switch.

This circuit is commonly used to light this lamp from either one of two locations.



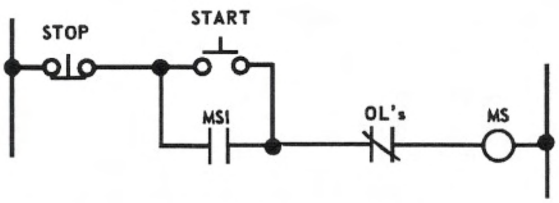
With both switches up (or down) the lamp lights; when one switch is up and the other down, the lamp receives no power.

In the circuit below the switches are mechanically connected so that both poles are either open or closed. Both lights are either on or off depending on switch position.



MOTOR STARTER CIRCUITS

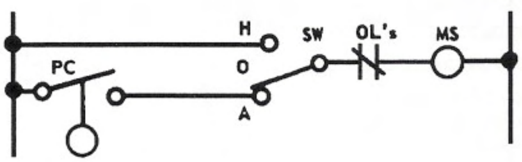
A further evolution of control circuits is shown in the wiring for a magnetic, non-reversing, motor starter, with momentary push button control stations.



The overload contacts (OLs) are part of the starter. They will open the motor starter (MS) coil circuit when motor line-current is excessive. They provide running overcurrent protection for the motor, and must be used in addition to branch circuit overcurrent protection devices if the motor does not have inherent or integral overcurrent protection.

The auxiliary contact of the motor starter (MS) has been labeled MSI (motor starter interlock). This contact closes when the MS is energized and establishes the "holding circuit" so that the "start" button may be released without de-energizing the MS. When the power contacts of the MS (not shown) close, the motor drives the devices connected to the motor shaft.

When pressure, temperature, liquid level, switches, or similar devices control motors, the following wiring diagram would be used.



A switch (SW) is shown in the circuit so that the motor: (a) can be run continuously, H position, (b) can be turned off, O position, or (c) can be operated by the pump control (PC) when SW is in the automatic, A position. When the liquid level is low (with SW in the A position) MS is energized and the pump runs. When the liquid level rises, PC opens, MS is de-energized, and the pump stops. With SW in the O position (off), MS can not be energized. With SW in the H position (hand), MS is continuously energized.

The system using PBs is often referred to as 3-wire control: it provides "undervoltage protection." This means that MS is de-energized on a loss of power, but remains de-energized when power returns. The start PB must be pressed to restart motors.

The system using simple switches is often referred to as 2-wire control: it provides under-voltage release. This means that MS is de-energized on a loss of power, but MS is re-energized upon power restoration if the switches are in a closed position.

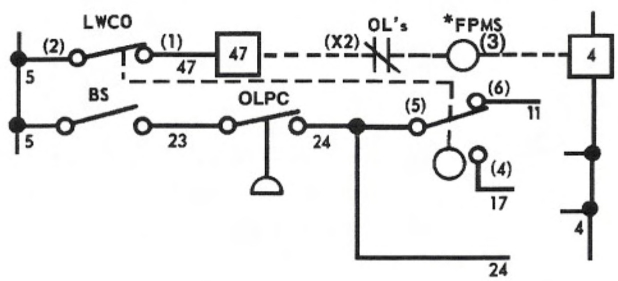
If automatic restart of a motor can not be tolerated, the 3-wire control system must be used.

Manual motor starters and circuit breakers do not provide undervoltage protection or undervoltage release. If either of these terms are in a specification, magnetic motor starters must be specified.

Manual motor starters can not be used with automatic control systems, because they have no provision for electrical operation; all action is mechanical. However, they do release if motor current is excessive, via the action of the overload devices incorporated within them.

IDENTIFICATION MARKINGS

The following notations identify circuits and terminal designations on schematic diagrams.



The numbers in parentheses denote the terminal numbers on the device itself.

The numbers below the lines denote circuit numbers. All wires and terminal blocks will be labeled to show circuit numbers.

The square terminal ☐ indicates that a field connection may be made to a terminal block (in the entrance box on the boiler) which has the corresponding number.

Solid lines show factory assembled wiring; broken lines represent field wiring or mechanical connections between parts within a complex device.

The asterisk (*) denotes that the item is not provided by the factory.

Splices or wire connections are identified with a dot●.

Wire cross-overs (no connection) are *NOT* identified with the dot.

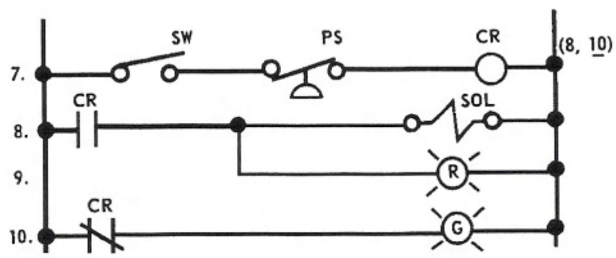

Connection


Cross-over; no connection

Letters above the device identify the device. They are as follows:

LWCO	Low Water Cut Off
FPMS	Feed Pump Motor Starter
OLS	Overloads
OLPC	Operating Pressure Control
BS	Burner Switch

Sometimes line numbers are listed to the left of the "hot" line and numbers are placed in parentheses to the right of relay coils, etc., so that the contacts of the device can be readily located.



The dash under the number in parentheses denotes that the contact is normally closed.

SCHEMATIC WIRING DIAGRAM (CB780)

General Information

In this section, the schematic diagram for a gas fired, full modulation steam boiler will be explained in detail. The logic used in this application can be applied to more complex diagrams. The task becomes relatively easy if care is taken to analyze the various systems such as the modulating control system, ignition system, main fuel system, limit circuit, oil pump system, water feed system, etc.

Refer to the wiring diagram in Figure 1 (Page 9).

In general, the diagram is read from left to right and from top to bottom. In reading the schematic diagram to understand the normal action, certain assumptions must be made:

1. Main power is present at terminals LL1, LL2, LL3 when disconnect switch is closed.
2. Control circuit power is derived through the control circuit transformer (CCT).
3. Boiler water is at the top of the normal level range.
4. Steam pressure is below the set point of the operating and high limit pressure controls.
5. All overloads (OLs) are closed; all fuses are in place.
6. All other conditions are such that the boiler will operate when the burner switch (BS) is closed.

The program relay provides automatic sequencing of the burner motor, damper motor, pilot valve, ignition spark, and the main fuel valve(s). A flame detector monitors the pilot and main flame and provides flame-out protection. Refer to Figure 2 (Page 10) for the operating sequence.

It may be desirable, but not necessary, to refer to the brochures which describe the program relay and the modulating damper motor. The internal circuit of the programmer is shown in a simplified schematic diagram in Figure 3 (Page 11).

Power Circuits

The main power circuit for the blower motor (BM) is shown at the top of the schematic diagram.

When the coil of the blower motor starter is energized in its proper sequence, the power contacts of the blower motor starter (BMS) close to allow the blower motor (BM) to run if the disconnect switch (DISC) is closed.

Control Circuits

The control circuit (Figure 1) is energized and the hot line has been extended downward on the left side of the diagram (circuit 5), and the ground line has been extended downward on the right side of the diagram (circuit 4).

Program relay terminal 4 is connected to the hot line and program relay terminal L2 is connected to the ground line so that the electronic circuit of the program relay is continuously energized.

A switching circuit shown is that of the top stage of the low water control (LWCO) commonly referred to as the pump control. When LWCO switch (2)-(1) is open, no action takes place because water level is at or above the high point of the normal water level. As water level drops, the top switch of LWCO closes providing control circuit power to either a feed pump motor starter which operates the boiler feed pump or to some other type of water control. A return to previous water level will cause top switch of the LWCO to re-open, thereby stopping the water input.

When the burner switch (BS) is open, (as shown) no action occurs; when it is closed, the hot line is extended through the limit circuit of the program relay. This circuit is composed of an operating limit control (OLC), a high limit control (HLC), the bottom stage of the low water control (LWCO), and low and high gas pressure switches (LGPS and HGPS). The limit circuit is completed when the circuit from terminal (4) to (6) of the program relay is completed.

There is a pre-ignition interlock circuit between programmer terminals (4) and (20). One of the gas valves has an attached switch (MGV-2AS) which is made when the valve is in a closed position. Completion of this circuit assures that the fuel valve is in a closed position prior to the ignition cycle.

With BS and OLC closed, control circuit power is also extended, via circuit 24, to the load demand light (LDL) to show that steam pressure is below the set point of OLC and that boiler should operate because there is a load demand.

Circuit 17 is not energized at this time and should be disregarded.

Program relay terminal (3) is energized upon a program relay safety lock-out and this circuit should be disregarded at this time.

When the program relay limit circuit and the pre-ignition interlock circuit are completed (control circuit power at program relay terminal (6)), the master relay of the program relay is energized and power is supplied to terminal (5) of the program relay. Power at terminal (5) then causes the coil of the blower motor starter (BMS) to be energized, which operates the blower motor (as previously explained under power circuits).

The primary winding of the damper motor transformer (DMT) has also been connected directly to circuits 4 and 5 so that the secondary circuit of DMT can supply the 24 volts necessary to power the modulating damper motor (MDM).

Terminals (13) and (14) are closed at the end of the operating cycle and they remain closed briefly at the start of a new cycle. This action short circuits terminals R and W of MDM which keeps the damper motor in a closed, or low fire, position at the start of an operating cycle.

When the master relay of the program relay is energized, terminals (13) and (12) of the program relay are shorted. This action short circuits terminals B and R of MDM and causes it to drive toward high fire. (Terminals (15) and (14) and the circuits connected thereto may be disregarded at the moment because these terminals are open circuited at this time.)

The air flow proving circuit must now be proven. Recall that terminal (5) has energized the coil of BMS to ultimately operate the blower motor. After the blower motor operates for a few seconds, the combustion air proving switch (CAPS) closes when it senses the build-up of air pressure in the front head of the boiler.

This action, along with the closing of the blower motor starter interlock (BMSI), extends control circuit power to terminal (7) of the program relay. This provides an internal holding circuit within a certain time limit and allows normal operation to continue.

Toward the end of the pre-purging period, program terminals (13) and (12) are open circuited and terminals (13) and (14) are shorted. This action provides a short circuit on MDM terminals R and W which causes the damper motor to return to a closed or low fire, position.

At the end of the pre-purge, program relay terminal (8) is energized and control circuit power is extended to the ignition transformer (IT) and gas pilot valve (GPV).

With air, gas and spark present, the pilot flame is established. When the flame detector (FD), connected to program relay terminals (F) and (G) detects flame, the flame relay within the program relay is energized.

At the end of the 10 second trial for pilot ignition period, program relay terminal (9) is energized and provides power to the main gas valves (MGV-1 and MGV-2). The normally open main gas vent valve (MGVV) is energized and closes. Control circuit power is also extended to the fuel valve light (FVL) to give a visual signal that the main fuel valve circuit is energized.

The main flame is ignited from the pilot flame and the flame detector (FD) monitors both flames.

At the end of the 10 second trial for main burner ignition period, program relay terminal (8) is de-energized. Consequently the gas pilot valve (GPV) closes, the ignition transformer (IT) is de-energized and the pilot flame is extinguished. The FD continues to monitor the main flame.

A few seconds later, program relay terminals (13) and (15) are shorted (terminal (14) is open circuited). The firing rate is now controlled by either the manual flame control (MFC) or modulating pressure control (MC) depending on the position of the manual-automatic selector switch (MAS).

With the switch in the automatic position (as shown) the W terminal of MDM is connected to the W terminal of MC, the R terminal of MDM is connected to the R terminal of MC via program relay terminals (13) and (15). The B terminal of MDM is connected to the B terminal of MC. Disregard MFC because its W and R circuits are open.

If boiler pressure is above the set point of MC, MDM remains in low fire. If boiler pressure is below set point of MC, MDM moves toward high fire. When the boiler load demand (as sensed by MC) and the firing rate (as determined by the position of MDM) are in equilibrium, no motion of MDM takes place. If pressure changes (because of a change in load), MC will move to cause a corresponding motion in MDM.

If the operating limit control (OLC) opens, or burner is manually turned off, terminal (6) of the program relay is de-energized. This immediately de-energizes the internal master and flame relays. Program relay terminal (9) is de-energized, the main gas valves (MGV-1 and MGV-2) close and fuel valve light (FVL) goes out. The vent valve (MGVV) is de-energized and opens.

Program relay terminals (13) and (14) remake (terminal (15) opens) to force MDM to low fire position because MDM circuit R to W is shorted.

Program relay terminal (5) remains energized so that blower motor (BM) still operates. At the end of the post-purge period, the program relay terminal (5) is de-energized and therefore BMS coil and BM are de-energized.

The control is now in readiness for subsequent recycling and when steam pressure drops to close the contacts of the operating control the burner again goes through its normal starting and operating cycle.

If a low water condition occurs (when BS and OLC are closed), the limit circuit opens and the action described above takes place. In addition, circuit 17 is energized via the bottom contact (4) of LWCO to illuminate the low water light (LWL) for visual indication of low water condition. Control circuit power is also supplied to entrance box terminal [17] for an optional low water alarm (LWA).

If a high steam pressure condition occurs (when BS is closed), limit circuit opens (OLC opens) and action described previously occurs. In addition, circuit 24 is de-energized and the load demand light (LDL) goes out to provide a visual indication that steam pressure is above set point of OLC.

If a flame failure condition occurs, all fuel valves are shut off in 2-4 seconds. After the internal safety switch of the program relay locks out and the master relay drops out, terminal (3) is energized. This provides control circuit power to circuit 16 to light the flame failure light (FFL) for a visual flame failure signal and to entrance box terminal [16] for an optional flame failure alarm (FFA).

Panel Connection Diagram

A panel connection diagram (see Figure 4, Page 12) is also provided with each unit to indicate the location of the various devices and to assist in their identification.

Customer's connections are clearly indicated in the external connection chart. For example, main power supply is to be connected to terminals LL1, LL2, LL3. The optional equipment may be connected to terminals 4 and 16 for flame failure alarm, terminals 4 and 17 for low water alarm and 48 and 49 for the feed water system.

NOTICE

Customer's connections are not to be made in the main control panel. They must be made in the entrance box located on the side of the boiler.

The Model CB780 Boiler Control panel is shown in Figure 5 (Page 13) .

Trouble Shooting

The schematic wiring diagram readily lends itself as a guide for trouble shooting.

One important difference in reading a schematic diagram for this purpose rather than for general information is that no assumptions can be made regarding switch positions, boiler water level, steam pressure, etc. The actual position of the switch must be determined (open or closed) from actual observation and the schematic diagram read with the actual position in mind. For example, if the burner switch (BS) is in the "on" position, the switch position of BS must be thought of in the closed position. Or, if the manual-automatic selector switch (MAS) is in the "man" position, the position of MAS must be thought of as if it were in the "man" position rather than in the "auto" position as shown on the diagram.

Using a voltmeter, each circuit can be checked and the fault isolated and corrected. Most of the circuitry checking can be done between the appropriate terminals on the terminal boards in the control cabinet or entrance box.

Costly downtime or delays can be prevented by systematic checks of the actual operation against the normal sequence to determine the stage at which performance deviates from normal. Following a routine may possibly eliminate overlooking an obvious condition, often one that is relatively simple to correct.

Careful observation and check, as well as a thorough knowledge of the operation of the combustion safeguard will be of invaluable assistance to the trouble shooter.

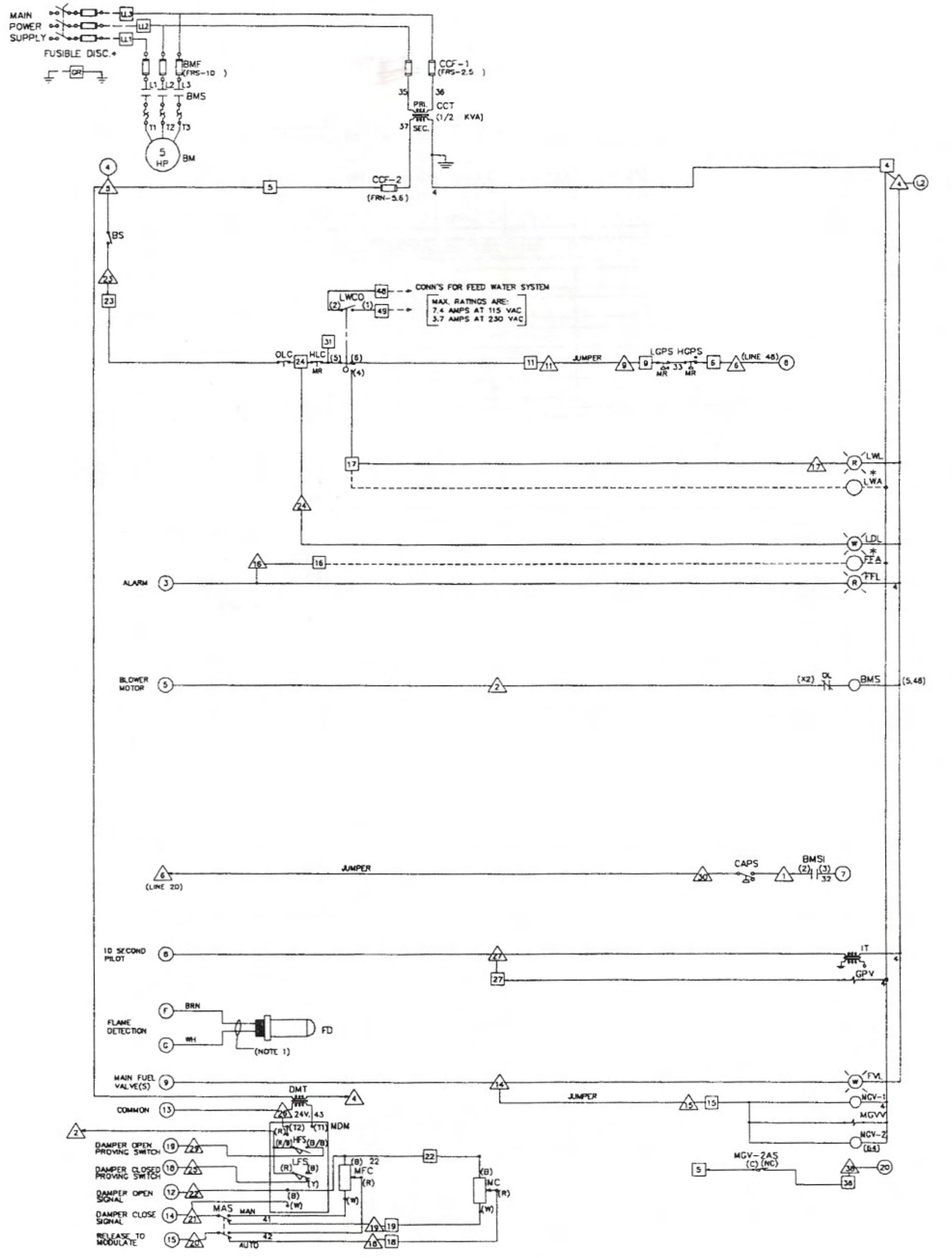


Figure 1. Model CB780 Boiler Wiring Diagram

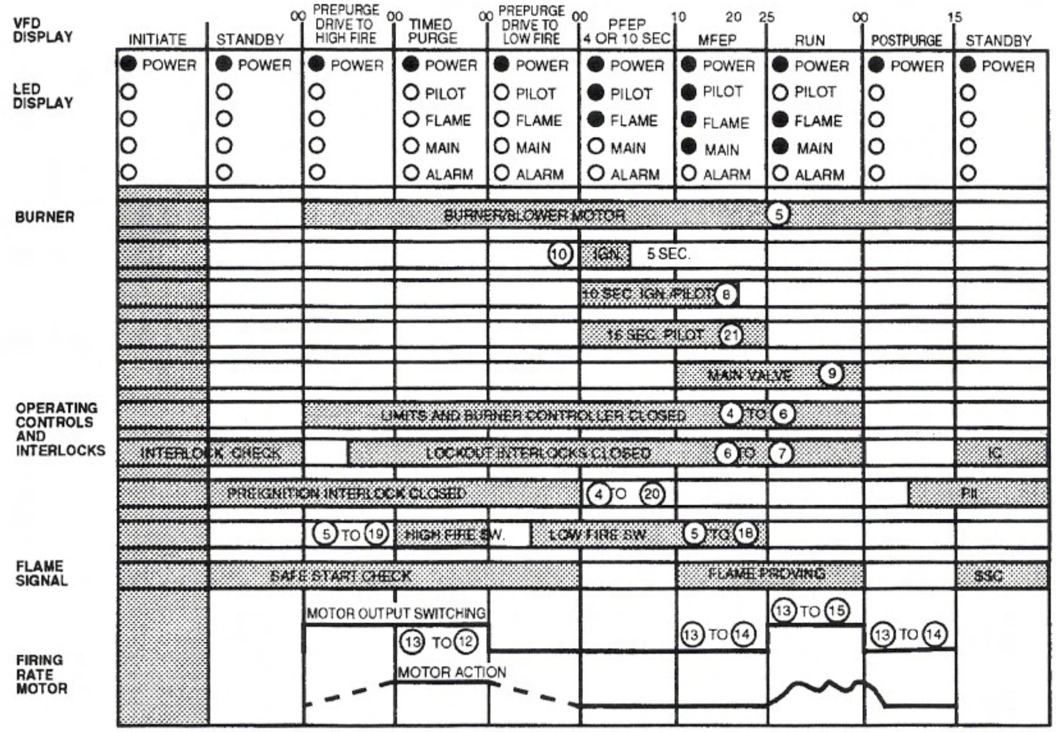


Figure 2. Model CB780 Operating Sequence

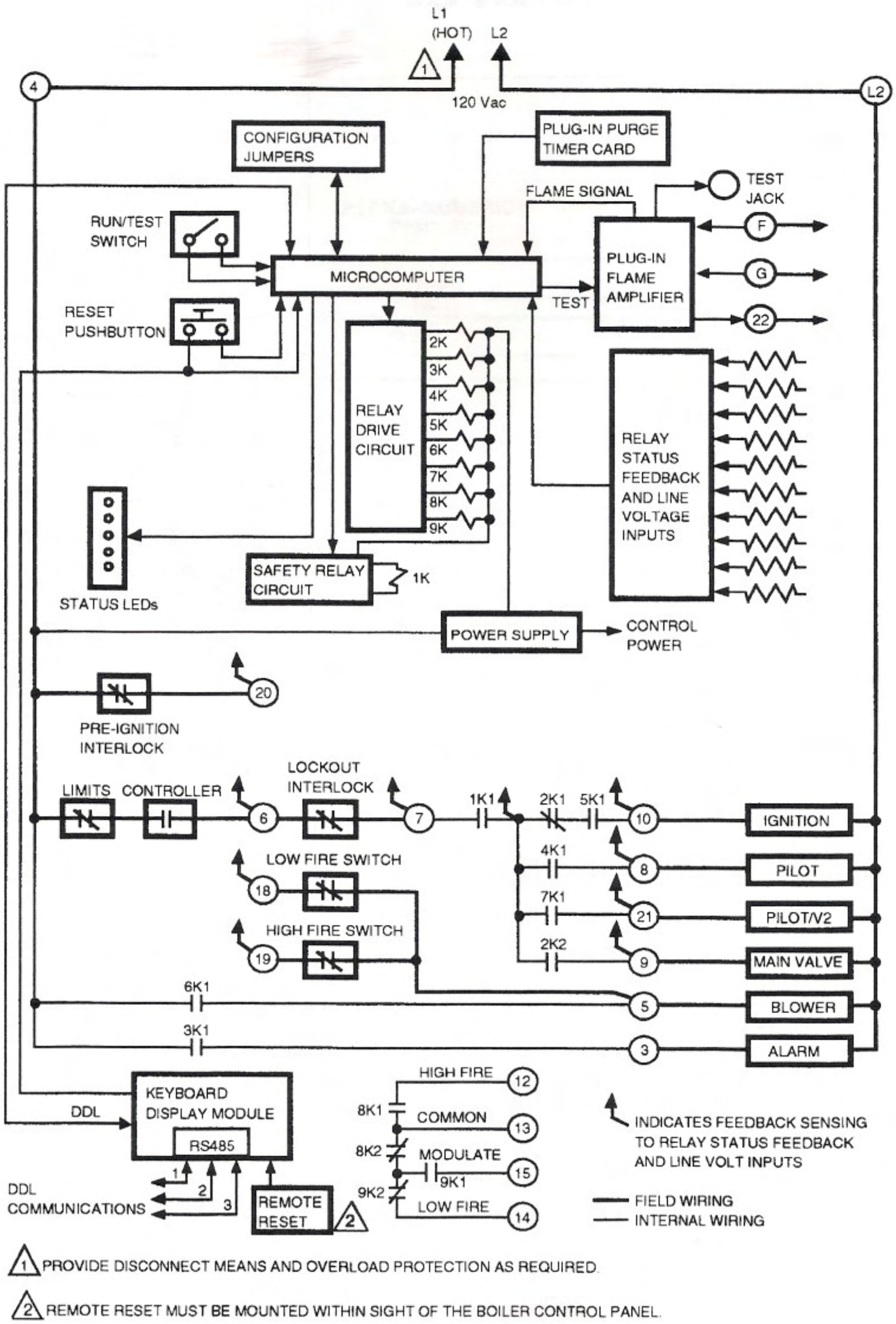


Figure 3. Model CB780 Simplified Internal Block Diagram

CONTROL PANEL TERMINALS

1,2,3,4,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30. 38,39,40.

JUMPER TERMINAL--4-4, 6-30, 9-11, 14-15.

ENTRANCE BOX TERMINALS

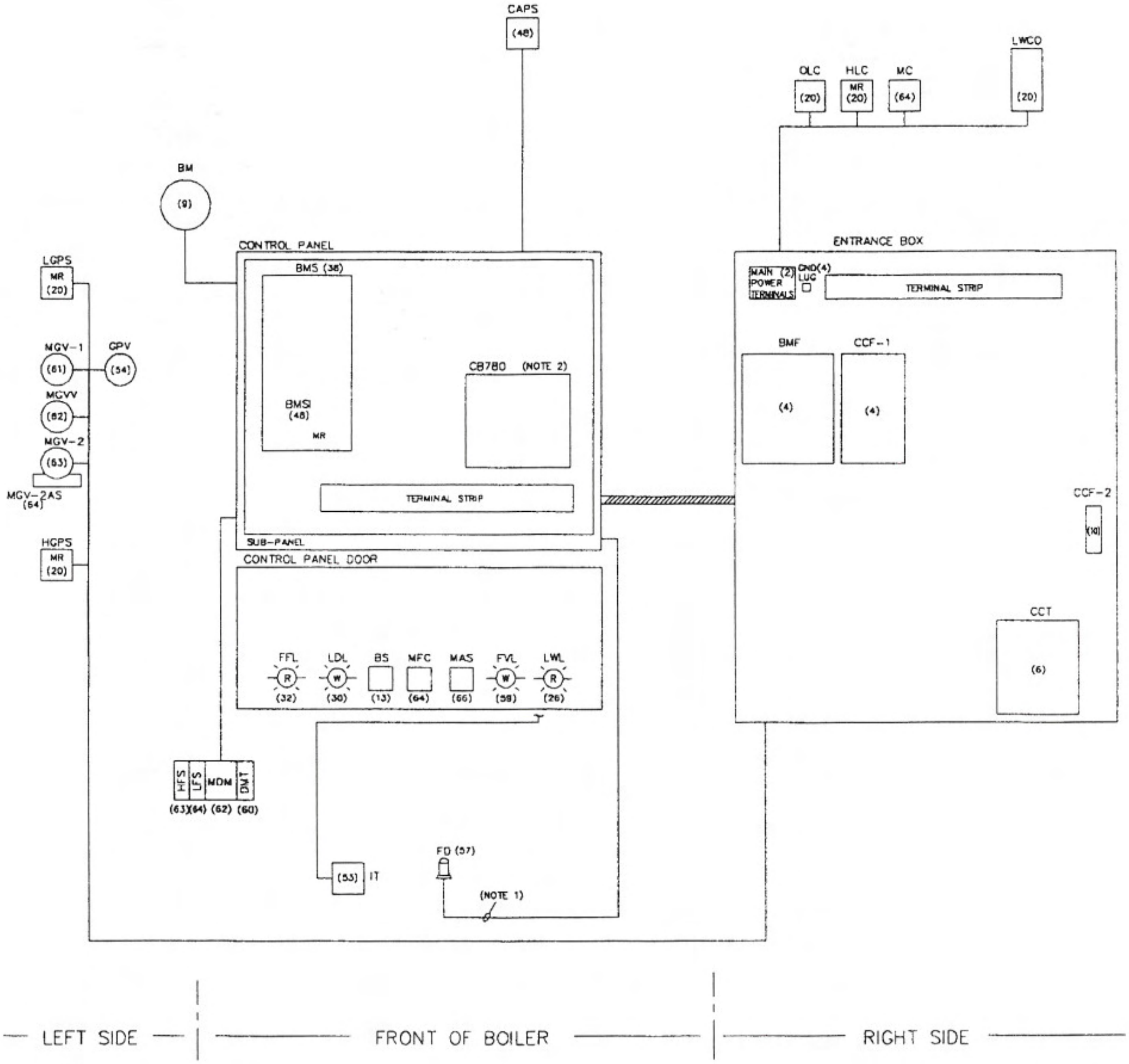
LL1,LL2,LL3

4,4,5,6. 9,11. 15,16,17,18,19,22,23,24,27. 31. 38, 40. 47,48,49,50.

JUMPER TERMINALS-4-4.

ENTRANCE BOX EXTERNAL CONNNECTIONS

DEVICE	FROM TERMINALS
MAIN POWER SUPPLY	LL1,LL2,LL3
FEED WATER SYSTEM	48,49
LWA *	4,17
FFA *	4,16



BLOCK SYMBOLS

BLOCKS SHOW RELATIVE POSITION OF DEVICES.

( ) SHOWS LINE NO. THAT THE DEVICE APPEARS ON, IN THE SCHEMATIC.

SCHEMATIC SYMBOLS

△ DENOTES CONTROL PANEL TERMINAL

□ DENOTES ENTRANCE BOX TERMINAL

( ) DENOTES TERMINAL DESIGNATION ON DEVICE

○ DENOTES PROGRAM RELAY TERMINAL

* CLEAVER-BROOKS DIVISION DOES NOT FURNISH

NOTES

NOTE 1- DETECTOR LEADS MUST BE RUN IN A SEPARATE CONDUIT.

NOTE 2- FOR FURTHER INFORMATION REGARDING PROGRAM RELAY SEE MANUAL 750-166.

ALL CONTROL SWITCHES ARE SHOWN IN THEIR NORMAL OPERATING POSITION. THE BURNER SEQUENCE IS OFF AND IN THE READY STATE, WITH THE BURNER SWITCH (BS) OPEN.

115 V. WIRE IS #14 AWG UNLESS OTHERWISE NOTED

WIRING SHOWN BY BROKEN LINES IS NOT FURNISHED BY CLEAVER-BROOKS DIVISION.

SEE FORM C23-3862 FOR MEANING OF ABBREVIATED DEVICES ADDITIONAL DEVICES AS FOLLOWS:

Figure 4. Model CB780 Panel Connection Diagram

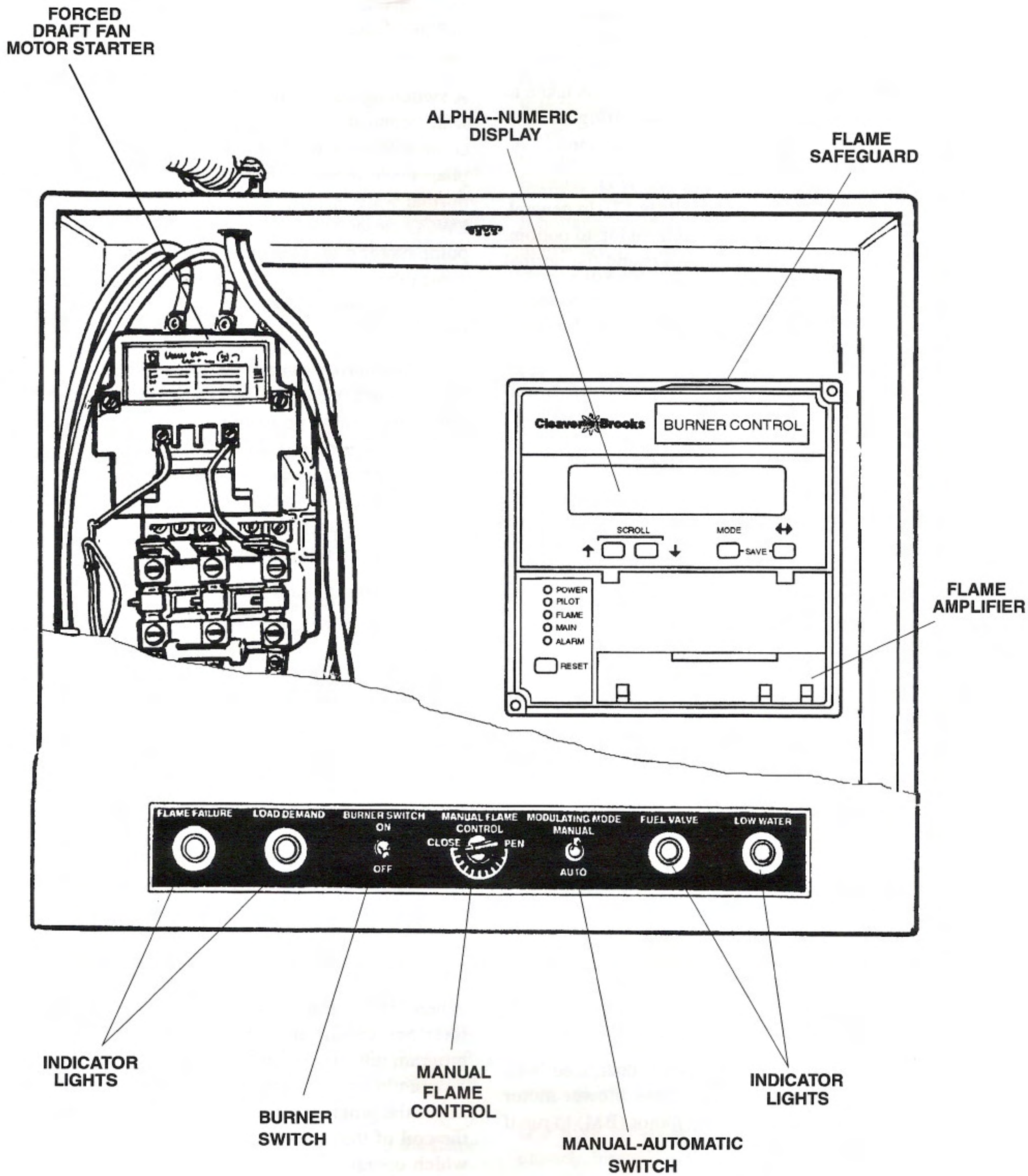


Figure 5. Model CB780 Control Panel

SCHEMATIC WIRING DIAGRAM (CB100E)

General Information

In this section, the schematic diagram for a gas fired, full modulation steam boiler will be explained in detail. The logic used in this application can be applied to more complex diagrams. The task becomes relatively easy if care is taken to analyze various systems such as the modulating control system, ignition system, main fuel system, limit circuit, oil pump system, water feed system, etc.

Refer to the wiring diagram in Figure 6 (Page 17). In general, the diagram is read from left to right and from top to bottom. In reading the schematic diagram to understand the normal action, certain assumptions must be made:

1. Main power is present at terminals LL1, LL2, LL3 when disconnect switch is closed.
2. Control circuit power is derived through the control circuit transformer (CCT).
3. Boiler water is at the top of the normal level range.
4. Steam pressure is below the set point of the operating and high limit pressure controls.
5. All overloads (OLs) are closed; all fuses are in place.
6. All other conditions are such that the boiler will operate when the burner switch (BS) is closed.

The program relay provides automatic sequencing of the burner motor, damper motor, pilot valve, ignition spark, and the main fuel valve(s). A flame detector monitors the pilot and main flame and provides flame-out protection. Refer to Figure 7 (Page 18) for the operating sequence.

It may be desirable, but not necessary, to refer to the brochures which describe the program relay and the modulating damper motor. The internal circuit of the programmer is shown in a simplified schematic diagram in Figure 8 (Page 19).

Power Circuits

The main power circuit for the blower motor (BM) is shown at the top of the schematic diagram (Figure 6, Page 17).

When the coil of the blower motor starter is energized in its proper sequence, the power contacts of the blower motor starter (BMS) close to allow the blower motor (BM) to run if the disconnect switch (DISC) is closed.

Control Circuits

The control circuit is (Figure 6, Page 17) energized and the hot line has been extended downward on the left side of the diagram (circuit 5), and the ground line has been extended downward on the right side of the diagram (circuit 4).

Program relay terminal (L1) is connected to the hot line and program relay terminal (L2) is connected to the ground line so that the electronic circuit of the program relay is continuously energized.

A switching circuit shown is that of the top stage of the low water control (LWCO) commonly referred to as the pump control. When LWCO switch (2)-(1) is open, no action takes place because water level is at or above the high point of the normal water level. As water level drops, the top switch of LWCO closes providing control circuit power to either a feed pump motor starter which operates the boiler feed pump or to some other type of water control. A return to previous water level will cause top switch of the LWCO to re-open, thereby stopping the water input.

When the burner switch (BS) is open, (as shown) no action occurs; when it is closed, the hot line is extended through the limit circuit of the program relay. This circuit is composed of an operating limit control (OLC), a high limit control (HLC), the bottom stage of the low water control (LWCO), and low and high gas pressure switches (LGPS and HGPS). The limit circuit is completed when the circuit from terminal (L1) to (13) of the program relay is completed.

There is a pre-ignition interlock circuit between programmer terminals (13) and (3). One of the gas valves has an attached switch (MGV-2AS) which is made when the valve is in a closed position. Completion of this circuit assures that the fuel valve is in a closed position prior to the ignition cycle.

With BS and OLC closed, control circuit power is also extended, via circuit 24, to the load demand light (LDL) to show that steam pressure is below the set point of OLC and that boiler should operate because there is a load demand.

Circuit 17 is not energized at this time and should be disregarded.

Program relay terminal (A) is energized upon a program relay safety lock-out and this circuit should be disregarded at this time.

When the program relay limit circuit and the pre-ignition interlock circuit are completed (control circuit power at program relay terminals (13) and (3)), the master relay of the program relay is energized and power is supplied to terminal (M) of the program relay. Power at terminal (M) then causes the coil of the blower motor starter (BMS) to be energized, which operates the blower motor (as previously explained under power circuits).

The primary winding of the damper motor transformer (DMT) has also been connected directly to circuits 4 and 5 so that the secondary circuit of DMT can supply the 24 volts necessary to power the modulating damper motor (MDM).

Terminals (10) and (12) are closed at the end of the operating cycle and they remain closed briefly at the start of a new cycle. This action short circuits terminals R and W of MDM which keeps the damper motor in a closed, or low fire, position at the start of an operating cycle.

When the master relay of the program relay is energized, terminals (10) and (X) of the program relay are shorted. This action short circuits terminals B and R of MDM and causes it to drive toward high fire. (Terminals (11) and (12) and the circuits connected thereto may be disregarded at the moment because these terminals are open circuited at this time.)

The air flow proving circuit must now be proven. Recall that terminal (M) has energized the coil of BMS to ultimately operate the blower motor. After the blower motor operates for a few seconds, the combustion air proving switch (CAPS) closes when it senses the build-up of air pressure in the front head of the boiler.

This action, along with the closing of the blower motor starter interlock (BMSI), extends control circuit power to terminal (P) of the program relay. This provides an internal holding circuit within a certain time limit and allows normal operation to continue.

Toward the end of the pre-purging period, program terminals (10) and (X) are open circuited and terminals (10) and (12) are shorted. This action provides a short circuit on MDM terminals R and W which causes the damper motor to return to a closed or low fire, position..

At the end of the pre-purge, program relay terminal (5) is energized and control circuit power is extended to the ignition transformer (IT) and gas pilot valve (GPV).

With air, gas and spark present, the pilot flame is established. When the flame detector (FD), connected to program relay terminals (S1) and (S2), detects flame, the flame relay within the program relay is energized.

At the end of the 10 second trial for pilot ignition period, program relay terminal (7) is energized and provides power to the main gas valves (MGV-1 and MGV-2) The normally open main gas vent valve (MGVV) is energized and closes. Control circuit power is also extended to the fuel valve light (FVL) to give a visual signal that the main fuel valve circuit is energized.

The main flame is ignited from the pilot flame and the flame detector (FD) monitors both flames.

At the end of the 10 second trial for main burner ignition period, program relay terminal (5) is de-energized. Consequently the gas pilot valve (GPV) closes, the ignition transformer (IT) is de-energized and the pilot flame is extinguished. The FD continues to monitor the main flame.

A few seconds later, program relay terminals 10 and 11 are shorted (terminal 12 is open circuited). The firing rate is now controlled by either the manual flame control (MFC) or modulating pressure control (MC) depending on the position of the manual-automatic selector switch (MAS).

With the switch in the automatic position (as shown) the W terminal of MDM is connected to the W terminal of MC, the R terminal of MDM is connected to the R terminal of MC via program relay terminals (10) and (11). The B terminal of MDM is connected to the B terminal of MC. Disregard MFC because its W and R circuits are open.

If boiler pressure is above the set point of MC, MDM remains in low fire. If boiler pressure is below set point of MC, MDM moves toward high fire. When the boiler load demand (as sensed by MC) and the firing rate (as determined by the position of MDM) are in equilibrium, no motion of MDM takes place. If pressure changes (because of a change in load), MC will move to cause a corresponding motion in MDM.

If the operating limit control (OLC) opens, or burner is manually turned off, terminal (13) of the program relay is de-energized. This immediately de-energizes the internal master and flame relays. Program relay terminal (7) is de-energized, the main gas valves (MGV-1 and MGV-2) close and fuel valve light (FVL) goes out. The vent valve (MGVV) is de-energized and opens.

Program relay terminals (10) and (12) remake (terminal (11) opens) to force MDM to low fire position because MDM circuit R to W is shorted.

Program relay terminal (M) remains energized so that blower motor (BM) still operates. At the end of the post-purge period, the program relay terminal (M) is de-energized and therefore BMS coil and BM are de-energized.

The control is now in readiness for subsequent recycling and when steam pressure drops to close the contacts of the operating control the burner again goes through its normal starting and operating cycle.

If a low water condition occurs (when BS and OLC are closed), the limit circuit opens and the action described above takes place. In addition, circuit 17 is energized via the bottom contact (4) of LWCO to illuminate the low water light (LWL) for visual indication of low water condition. Control circuit power is also supplied to entrance box terminal [17] for an optional low water alarm (LWA).

If a high steam pressure condition occurs (when BS is closed), limit circuit opens (OLC opens) and action described previously occurs. In addition, circuit 24 is de-energized and the load demand light (LDL) goes out to provide a visual indication that steam pressure is above set point of OLC.

If a flame failure condition occurs, all fuel valves are shut off in 4 seconds. After the internal safety switch of the program relay locks out and the master relay drops out, terminal (A) is energized. This provides control circuit power to circuit 16 to light the flame failure light (FFL) for a visual flame failure signal and to entrance box terminal 16 for an optional flame failure alarm (FFA).

Panel Connection Diagram

A panel connection diagram (see Figure 9, Page 20) is also provided with each unit to indicate the location of the various devices and to assist in their identification. Because this diagram would be virtually unreadable if all wires were shown, the circuit numbers have been placed adjacent to the terminals on the device itself (note that circuit numbers and terminal board (TB) numbers are identical).

Customer's connections are clearly indicated in the external connection chart. For example, main power supply is to be connected to terminals LL1, LL2, LL3. The optional equipment may be connected to terminals 4 and 16 for flame failure alarm, terminals 4 and 17 for low water alarm and 48 and 49 for the feed water system.

The Model CB100E Boiler Control panel is shown in Figure 10 (Page 21).

NOTICE

Customer's connections are not to be made in the main control panel. They must be made in the entrance box located on the side of the boiler.

Trouble Shooting

The schematic wiring diagram readily lends itself as a guide for trouble shooting.

One important difference in reading a schematic diagram for this purpose rather than for general information is that no assumptions can be made regarding switch positions, boiler water level, steam pressure, etc. The actual position of the switch must be determined (open or closed) from actual observation and the schematic diagram read with the actual position in mind. For example, if the burner switch (BS) is in the "on" position, the switch position of BS must be thought of in the closed position. Or, if the manual-automatic selector switch (MAS) is in the "man" position, the position of MAS must be thought of as if it were in the "man" position rather than in the "auto" position as shown on the diagram.

Using a voltmeter, each circuit can be checked and the fault isolated and corrected. Most of the circuitry checking can be done between the appropriate terminals on the terminal boards in the control cabinet or entrance box.

Costly downtime or delays can be prevented by systematic checks of the actual operation against the normal sequence to determine the stage at which performance deviates from normal. Following a routine may possibly eliminate overlooking an obvious condition, often one that is relatively simple to correct.

Careful observation and check, as well as a thorough knowledge of the operation of the combustion safeguard will be of invaluable assistance to the trouble shooter.

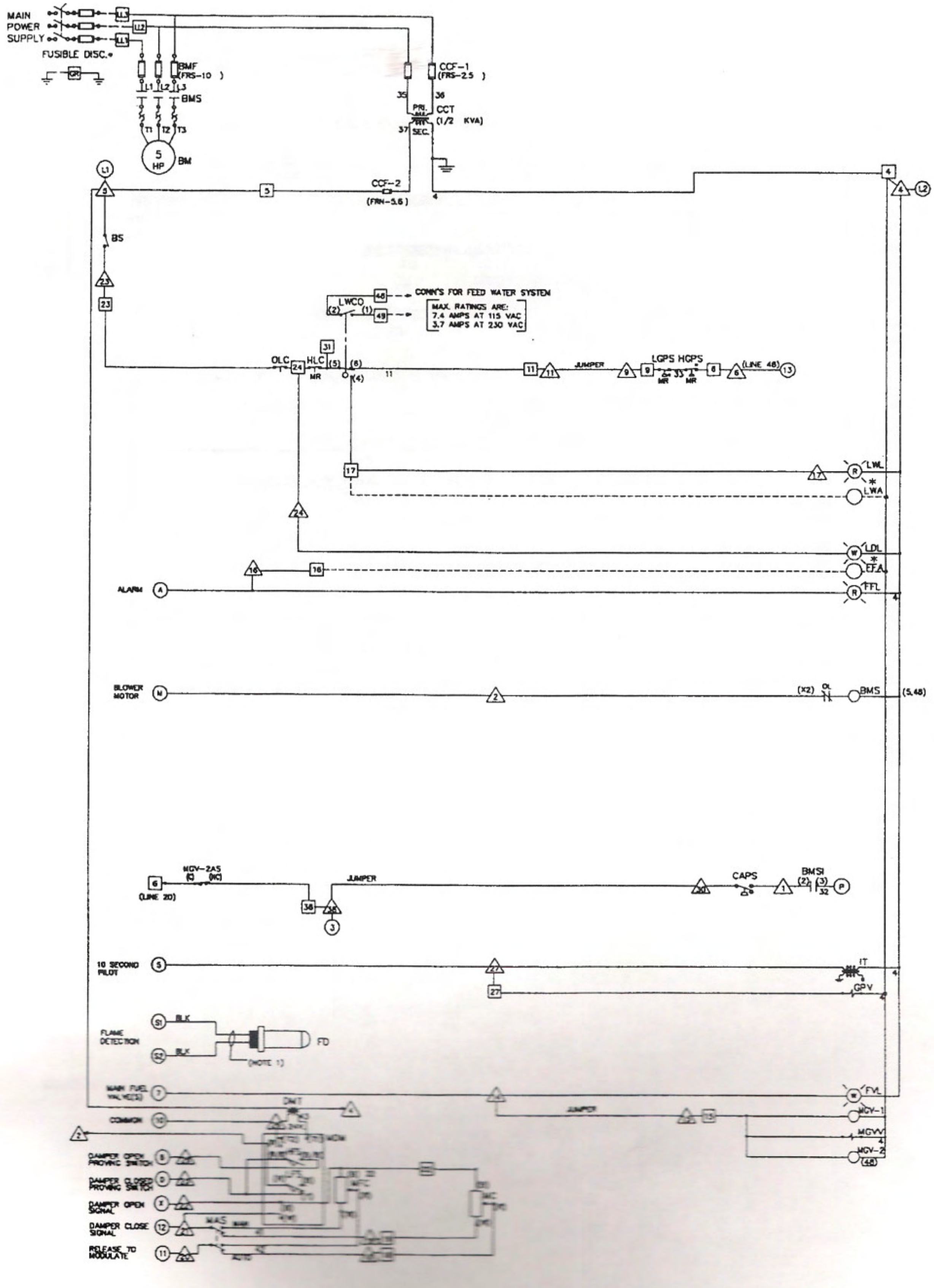


Figure 6. Model CB100E Boiler Schematic Diagram

CONTROL PANEL TERMINALS

1,2,3,4,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30, 38,39,40.

JUMPER TERMINAL-4-4, 30-38,9-11,14-15.

ENTRANCE BOX TERMINALS

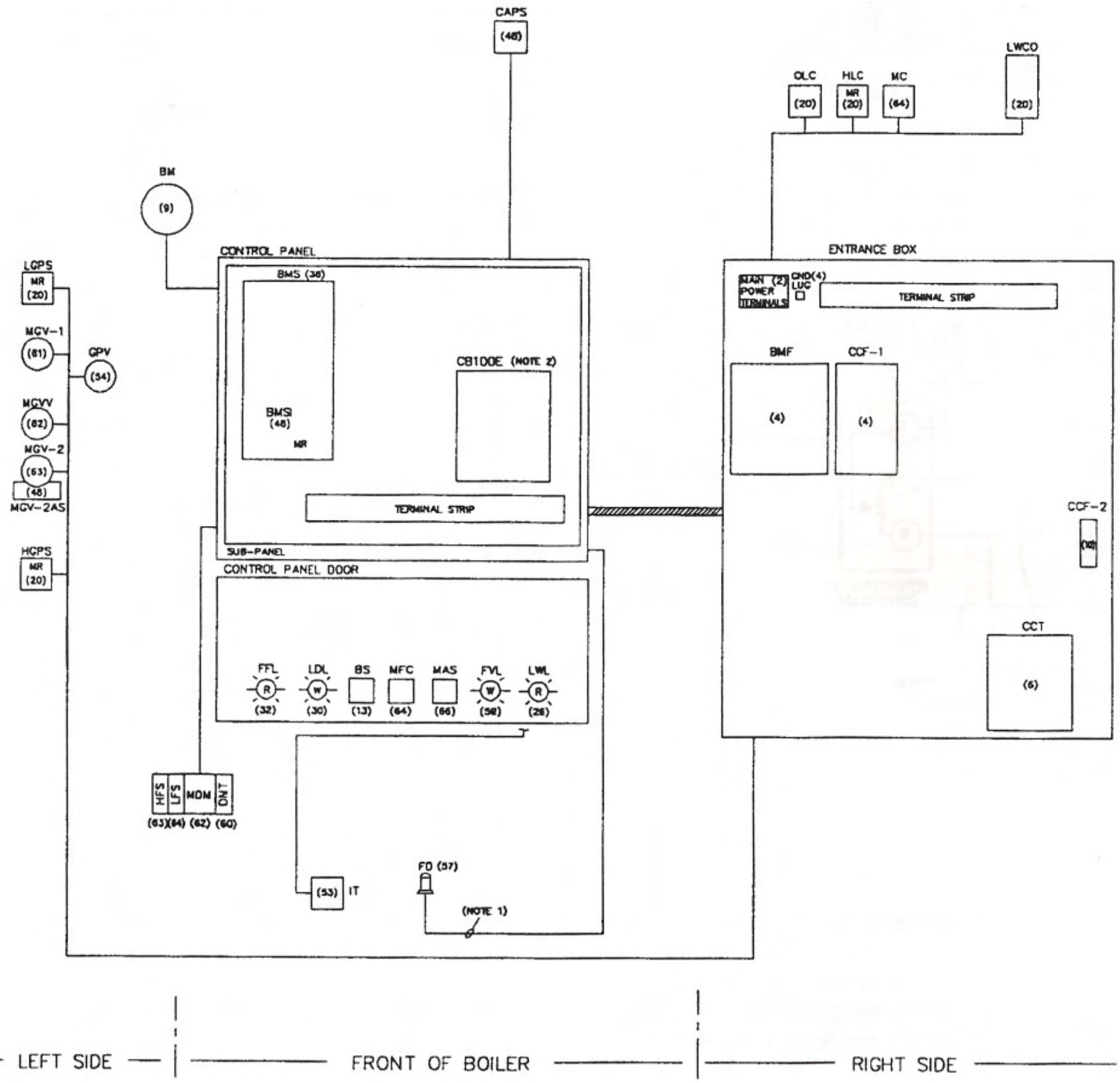
LL1,LL2,LL3

4,4,5,6, 9,11, 15,16,17,18,19,22,23,24,27, 31, 38, 40, 47,48,49,50.

JUMPER TERMINALS-4-4,

ENTRANCE BOX EXTERNAL CONNNECTIONS

DEVICE	FROM TERMINALS
MAIN POWER SUPPLY	LL1,LL2,LL3
FEED WATER SYSTEM	48,49
LWA *	4,17
FFA *	4,16



BLOCK SYMBOLS

BLOCK SHOWS RELATIVE POSITION OF DEVICES.

( ) SHOWS LINE NO. THAT THE DEVICE APPEARS ON, IN THE SCHEMATIC.

SCHEMATIC SYMBOLS

△ DENOTES CONTROL PANEL TERMINAL

□ DENOTES ENTRANCE BOX TERMINAL

( ) DENOTES TERMINAL DESIGNATION ON DEVICE

○ DENOTES PROGRAM RELAY TERMINAL

* CLEAVER-BROOKS DIVISION DOES NOT FURNISH

NOTES

NOTE 1- DETECTOR LEADS MUST BE RUN IN A SEPARATE CONDUIT.

NOTE 2- FOR FURTHER INFORMATION REGARDING PROGRAM RELAY SEE FORM CB7846.

ALL CONTROL SWITCHES ARE SHOWN IN THEIR NORMAL OPERATING POSITION. THE BURNER SEQUENCE IS OFF AND IN THE READY STATE, WITH THE BURNER SWITCH (BS) OPEN.

115 V. WIRE IS #14 AWG UNLESS OTHERWISE NOTED

WIRING SHOWN BY BROKEN LINES IS NOT FURNISHED BY CLEAVER-BROOKS DIVISION.

SEE FORM C23-3862 FOR MEANING OF ABBREVIATED DEVICES ADDITIONAL DEVICES AS FOLLOWS:

Figure 9. Model CB100E Boiler Panel Connections

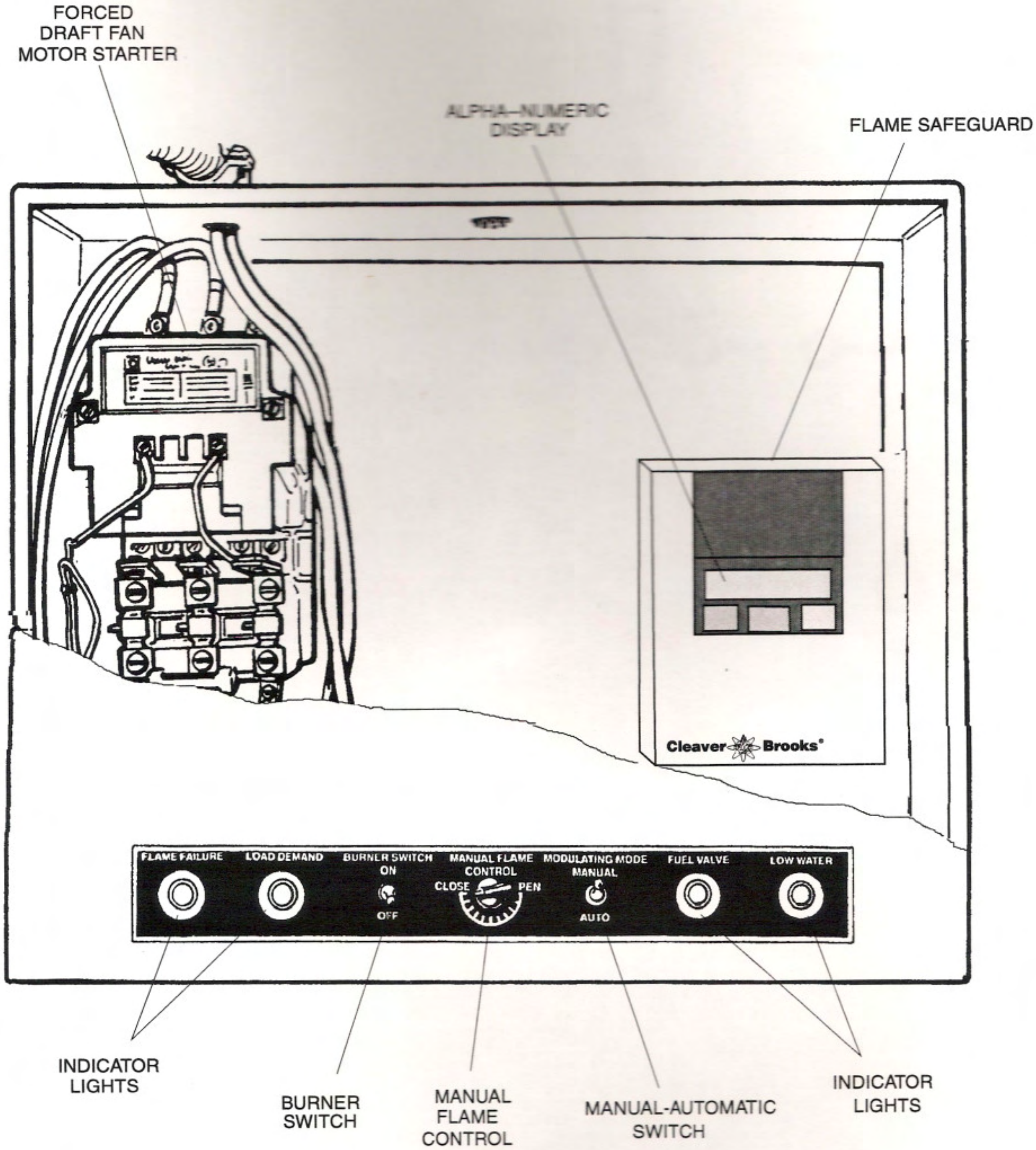


Figure 10. Model CB100É Control Panel

Cleaver-Brooks®

Performance Proven Worldwide

CB -7779-R1
4/97