



Electrode Boiler Model CEJS

Installation, Operation,
and Maintenance



750-272
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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 warnings may result in severe personal injury or death.

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

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

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

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

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

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

It is recommended that a boiler room log or record be maintained. Recording of daily, weekly, monthly and yearly maintenance activities and recording of any unusual operation will serve as a valuable guide to any necessary investigation. Most instances of major boiler damage are the result of operation with low water. We cannot emphasize too strongly the need for the operator to periodically check his 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.

It is essential to obtain the services of a qualified water treating company or a water consultant to recommend the proper boiler water treating practices.

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

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1 - INTRODUCTION

This manual contains descriptive, maintenance, operating, and parts information for the Cleaver-Brooks Electrode Steam Boiler Model CEJS. The CEJS is a three-phase four-wire high voltage steam-producing boiler with automatic control and limiting functions.

1.1-Description

The CEJS Electrode Steam Boiler is several systems integrated into a single unit to function as a heating system. The several systems making up the boiler are:

- The electrodes
- The circulating system (piping)
- The pressure vessel
- The control system

1.2-Operating principles

Electrode boilers utilize the conductive and resistive properties of water to carry electric current and generate steam. The electric current flows between the energized electrode and the two neutral points, the nozzle stock and the counter electrodes. The water streams are the conductors.

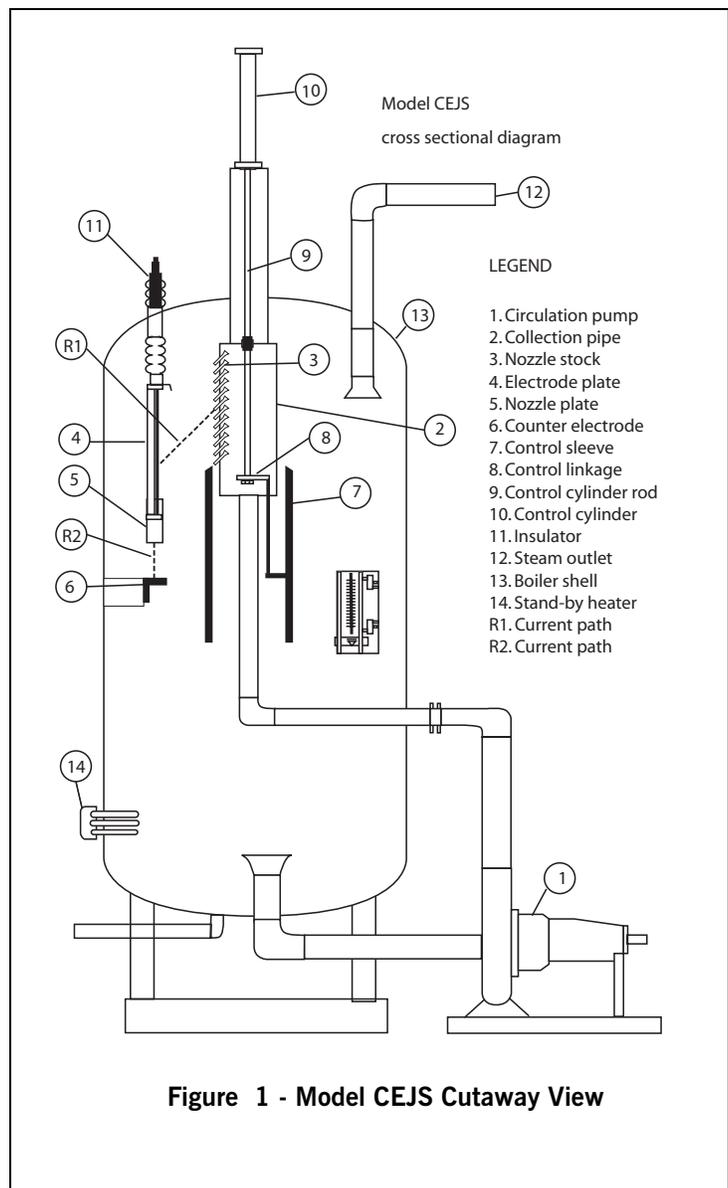
Since water has electrical resistance, this current flow generates heat directly in the water itself. As current flow increases, more heat is generated and more steam is produced.

Figure 1 is a typical boiler configuration, It is shown for the purpose of this explanation only. The actual configuration of your model will be found on the drawings which accompany the boiler.

Basic Principles

The Model CEJS High Voltage Steam Boiler generates heat by passing electrical current through the boiler water and uses the water as the resistor. In the cutaway view of the boiler, water is drawn from the bottom part of the boiler drum by the circulating pump (1) and forced up the center collection pipe (2) to the nozzle stock (3) where it is discharged through multiple nozzles with sufficient velocity to strike the electrode plate (4).

Electrical current now flows through R1, the streams of water, to the nozzle stock. The rate of flow is greatly in excess of the steaming rate, and water which is not vaporized from the nozzle streams falls to the bottom or collector portion of the



electrode and drains through the nozzle plate (5) which forms the bottom of the electrode. As the water falls from the electrode, it strikes the counter electrode (6) and a second current path R2 is established.

Since both the nozzle stock and the counter electrode are in contact with the boiler shell, they form the common connection points of a "Y" connected load.

At maximum power output with proper conductivity of the water all of the nozzles of the nozzle stock are discharging to the electrode plate at a constant rate. In order to regulate the output to match changes in system demand, and to maintain constant steam pressure, the regulating shield is positioned by a hydraulic cylinder. Vertical movement of the regulating shield results in a nearly linear change in power output (current flow) relative to the number of streams of water allowed to strike the electrodes. The change is not exactly linear because the flow rate from the nozzles varies according to the static head at the nozzle inlet. The time for full travel of the regulating shield can be 20 seconds or longer and varies according to required operating conditions.

Starting and stopping of the boiler is done by starting and stopping of the pump. The electrodes can remain energized when the pump is off, since no current can flow unless the pump is running. This mode of operation provides a 'soft start' and 'soft stop' feature.

In some cases, a standby heater is included. The standby heater is an immersion element type used to keep the boiler just below the minimum operating pressure during periods when steam production is not required. When the standby heater is used, the boiler can start producing steam in a much shorter time after a period of inactivity, as the water temperature has been maintained at a higher level. Keeping the boiler at temperature is also beneficial to the insulators and gasketed joints.

The boiler works in conjunction with other components within the same system, such as a deaerator or condensate return tank, which serve as a reservoir for the boiler feedwater. Condensate from the steam system is recovered at these points and chemical additives are added if needed. The treated makeup water is fed into the boiler by the feedwater pump through a modulating control valve.

Boiler water conductivity is tested during boiler operation by automatically drawing off small samples and passing them through a conductivity measuring cell. The conductivity signal is connected to the automatic conductivity controller. If conductivity is low, the chemical feed pump will be activated to add the necessary chemicals to bring up the conductivity. If conductivity is high, a solenoid bleed valve will be activated to evacuate the necessary amount of water and replace it with fresh makeup water.

The water level controller and level gauge are mounted on the water column. The gauge visually shows the level of water in the pressure vessel. The high and low water limits are mounted in the vessel. These devices are sensors for the automatic control system.

Regulating Steam Production

The electrical control system automatically positions the regulating shield to maintain the steam pressure of the boiler at the set point by matching steam output to the load on the steam system. Should the demand for steam exceed the boiler's rated capacity, the boiler's steam output is restricted by a current monitoring system in the electrical controls. Steam production may be automatically controlled by a pressure control, or manually by selecting the output desired using the 'POWER LIMIT' function on the boiler control panel overview screen.

The boiler control system operates primarily to regulate the boiler output to maintain constant steam pressure, but incorporates also a current monitoring system to prevent the boiler electrical demand from exceeding the design value - i.e. full load. The 'POWER LIMIT' is provided to enable the operating engineer to manually limit the boiler to less than full rated MW if necessary. The load regulating system uses the boiler MW as the controlled variable, and the system is therefore insensitive to changes in conductivity as long as adequate conductivity is maintained.

1.3-Advantages/performance benefits

100% of the electrical energy is converted into heat with no heat transfer or stack losses. Since the water has electrical resistance, this current flow generates heat directly in the water itself. The more current (amps) that flows, the more heat (BTU) that is generated and the more steam that is produced.

Low water protection is absolute since the absence of water prevents current from flowing and the electrode boiler from producing steam.

Unlike conventional electric boilers or fossil fuel boilers, nothing in the electrode boiler is at a higher temperature than the water itself (with the exception of the standby heater when the boiler is not in operation).

If scaling should occur in the boiler, it will electrically insulate the electrodes, reducing current flow and boiler output. There will be no loss in conversion efficiency. Cleaning the electrodes will restore capacity. There will be no heat buildup in the electrodes, no electrode burnout, and no danger to the boiler itself.

The efficient utilization of electrical energy enables the CEJS to provide a very high steam output within a small physical space.

2 - Installation

Installing the CEJS involves these major steps:

1. Installation of Piping
2. Mechanical installation of circulation pump, electrodes, and hydraulics
3. Wiring the electrical supply and interconnections
4. Preparation for startup
5. Initial startup and checkout procedures

Refer to the boiler drawings for exact details, measurements, and dimensions for the following instructions.

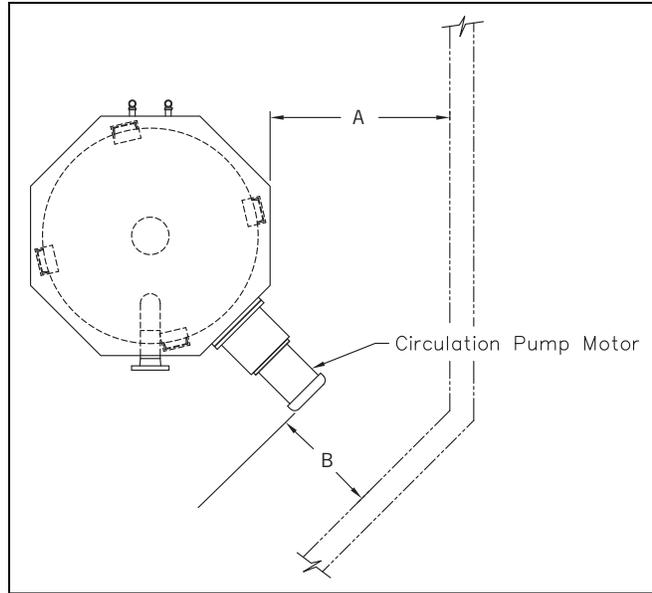
2.1-Location

Position the boiler on its pad and level it. Provide adequate clearances on all sides for maintenance and operation space (see Table 1).

Locate the control cabinet adjacent to the boiler so that the operator can observe boiler operation as necessary.

Table 1: Model CEJS Minimum Clearances.

Model Number	Minimum Clearances	
	A	B
CEJS-200	60"	30"
CEJS-400	60"	36"
CEJS-600	60"	36"
CEJS-900	60"	48"
CEJS-1200	60"	48"
CEJS-1800	60"	48"
CEJS-2400	60"	48"
CEJS-3000	60"	55"
CEJS-3600	60"	55"
CEJS-4200	60"	70"
CEJS-5000	60"	70"



2.2-Piping

For field installed piping refer to Figure 3 and the piping schematic for your boiler. Install all piping shown by dotted lines and all piping external to the boiler package. Components normally included as standard with CEJS boilers are described below.

Note: Different piping configurations are possible depending on boiler capacity. The diagram shows a typical application. Consult the piping diagram provided with your boiler for details specific to your installation.

Vent Line

It is necessary to vent air from the system during initial startup, filling, and draining of the boiler. From the top of the vessel a one inch vent pipe and easily accessible valve should be plumbed to within two (2) inches of the floor, in a location where escaping steam will not endanger those operating the boiler. This valve is opened at startup and is left open to allow air and a small amount of steam to escape. When the boiler reaches 100 psi, the vent valve should be closed and not opened again as long as positive pressure remains in the boiler.

Water column and gauge glass

The water column is a cylindrical chamber located on the outside of the boiler, usually in front. Two pipes connect it to the pressure vessel, one below the water line and one above. Thus, the water column duplicates the water level condition inside the boiler. The column is provided with a level gauge glass and a drain. The drain must be piped to a safe point of discharge such as a blowdown tank or outside drain, as the hot water evacuated will flash to steam under normal atmospheric conditions. The water column should be blown down once a day to clear out accumulated sediment (see Section 8 - Maintenance). During normal operation the water column drain should be closed.

The High Water and High High Water limit probes are located in the boiler vessel. These probes should be checked at installation. The lower probe is High Water and the upper probe is High High Water. Note which probe is which and tag them to make wiring easier.



Figure 2 - Water Column

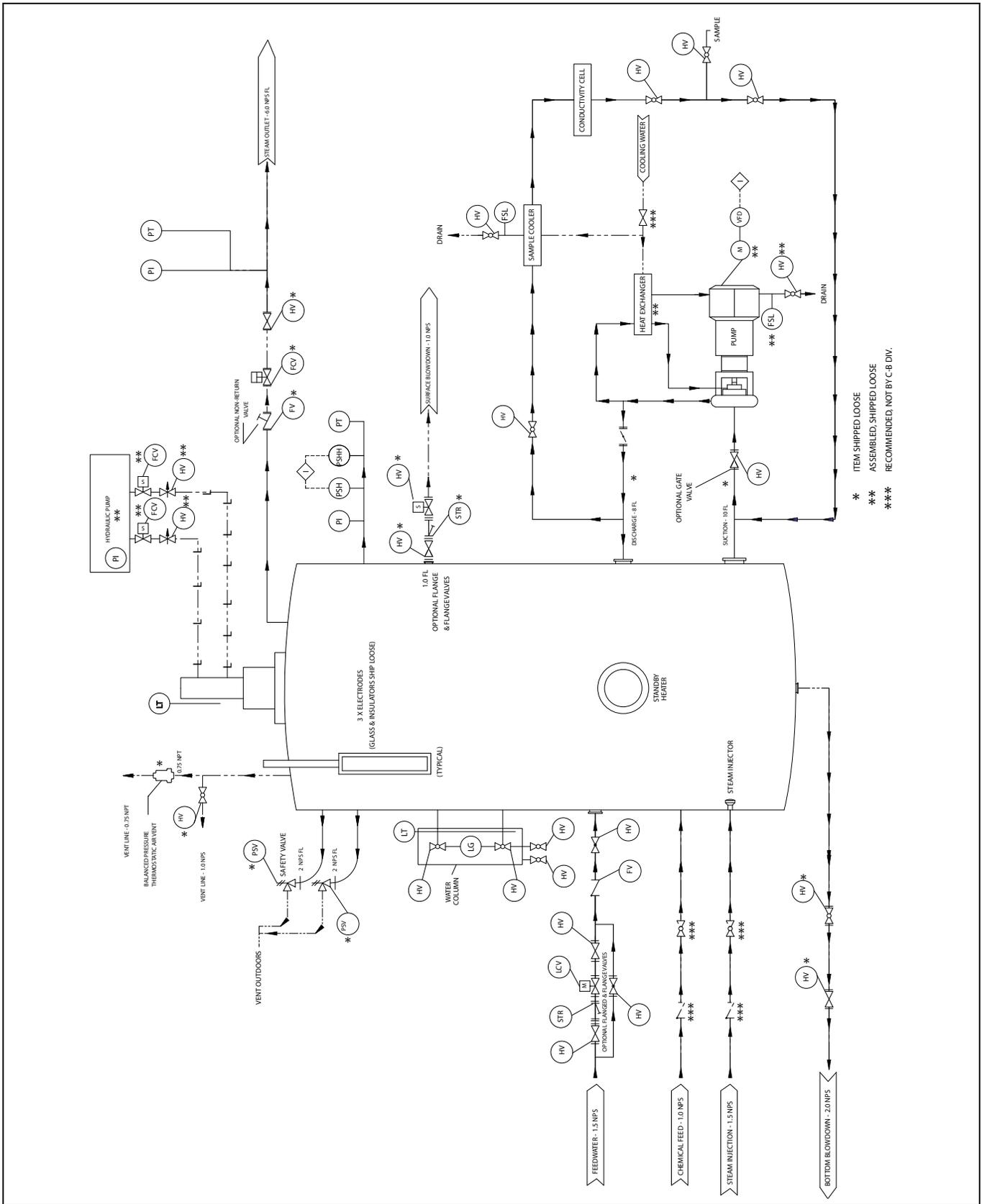


Figure 3 - Typical piping configuration

Feedwater and water level controller

Feedwater is piped into the boiler near the base of the pressure vessel. The feedwater regulating valve, check valve, and gate valve are normally furnished with the boiler.

A bypass (requiring three valves) may be installed around the feed water regulating valve to facilitate valve replacement.

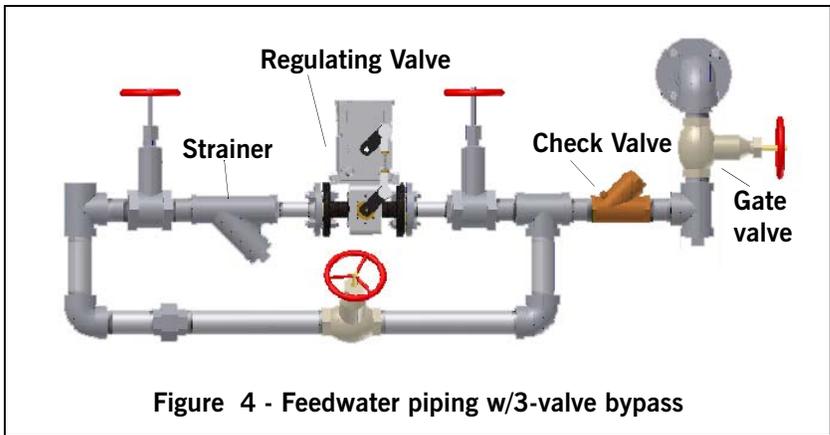


Figure 4 - Feedwater piping w/3-valve bypass

The water level transmitter

mounted on the water column is a modulating 4-20 mA type. In order to maintain a consistent water level in the system, the transmitter signal opens the feedwater valve when the boiler drops below the acceptable operating level and closes it again when water level rises. Feedwater may also be added manually through the customer bypass.

Pressure controls

A boiler pressure gauge, pressure transmitter, and high pressure limit control are piped to a manifold with unions for each branch. The manifold is piped to a coupling in the steam space of the boiler (above the waterline). The piping schematic shows actual configuration for each boiler.

A system pressure gauge and transmitter are installed downstream of the steam outlet back-pressure valve. Their function is to give a comparative reading between vessel pressure and pressure in the pipes downstream of the boiler steam valves.

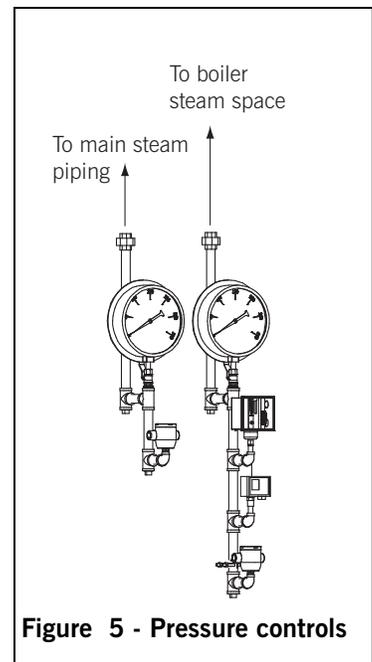


Figure 5 - Pressure controls

Caution

The discharge from the blowdown piping is extremely hot and must be piped to a safe point of discharge.

A blowdown tank (optional) may be used as a means of safe disposal of blowdown discharge. The blowdown pipe between the valves and blowdown tank should provide for connection of additional hot water from the surface blowdown line, water column drain, etc.

Sampling system and surface blowdown

The piping schematic will show the specific details of these lines. The most common configuration of the sample line is a gate valve at the vessel, a sample cooler, and sometimes a flow control metering valve to a fitting holding the conductivity cell. From the conductivity cell, the water is piped back to the boiler. The sample flow should be at the minimum that will give an accurate measurement.

The conductivity cell takes a reading of the conductivity of the boiler water and feeds the signal to the conductivity controller. The conductivity controller automatically oversees the conductivity of the boiler water, keeping it within the limits acceptable for proper operation (see 4.3 - Boiler Control Circuits).

The surface blowdown line usually contains a gate valve, solenoid valve, and a flow control metering valve. It operates when the conductivity of the water is too high, drawing off some of the water from the vessel so that fresh makeup may be added to dilute the conductivity. It is a blowdown line and must be piped to drain in a safe area such as a blowdown tank.



Figure 6 - Sample cooler

Safety Valves

Safety valves are standard with this boiler. The valve discharge must be piped and vented to the atmosphere outside the boiler room at a location that is safe for persons in the area. These valves must be piped in such a manner that they will not hinder access to any of the boiler controls. Use a gravity drain for condensate near the safety valves, and at any low points below the valve seats. Small condensate drain valves may be used if they are left open during operation and are piped to drain in a safe location.

Steam outlet

The steam outlet size is determined by the boiler's capacity and operating pressure. The piping schematic will give the actual size. Usually, there will be a gate valve directly outside the boiler, and a back pressure regulating valve with its controller.

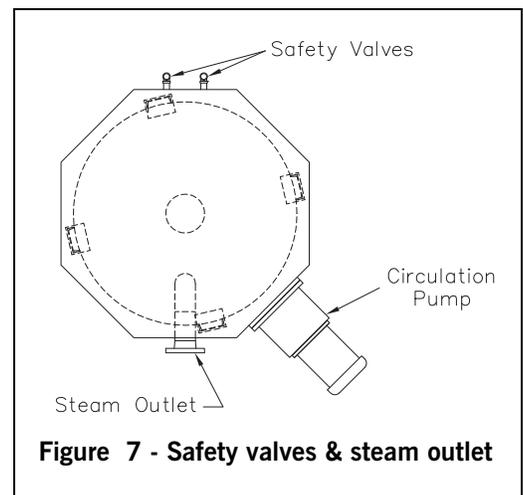


Figure 7 - Safety valves & steam outlet

Chemical feed pump

The chemical feed pump is not part of the standard boiler package, but can be added as part of a completely automatic conductivity control system. The pump is actuated by a signal from the conductivity control circuit if a low conductivity condition is sensed in the boiler water. It pumps chemical into the boiler to bring the conductivity to the correct level for operation. The pump starter may be located in the medium voltage compartment.

2.3-Mechanical

Circulation pump

The circulation pump is a pre-assembled unit. Installation consists of bolting it in the mounting flange with gaskets and tightening the bolts on the discharge manifold and pump flange. The pump contains a mechanical seal which in some installations may require the connection of a cooling water inlet and drain.

Install the pump wiring and check:

- 1.The voltage rating on the motor against the supply voltage.
- 2.The rotation of the pump motor. The proper direction is marked on the motor mount. If the motor rotates backwards, reverse any two wires.

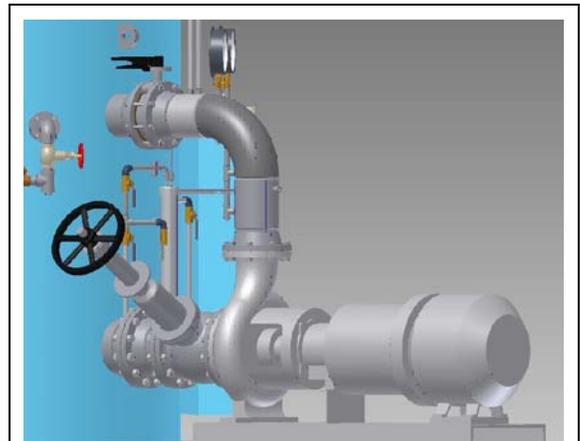


Figure 8 - Circulation Pump

Electrode Installation

Assemble high voltage cage. Electrode installation includes installing the electrode lead-through and the electrode housing, positioning the electrode housing, and positioning the counter electrode. The electrode housing must be installed squarely and at equal distances from the nozzles, and so that the water streams discharged from the nozzles strike the center of the electrode target plate.

Install the electrode rod assembly through the electrode nozzle in the vessel with connected electrode box and target plates. Adjust connection bolts until the electrode plates are positioned at an equal distance from the nozzle stock. After ensuring the electrode boxes are properly positioned, tighten the electrode rod nuts to 500 ft lb of torque. This will compress the spring washer to almost fully flat.

Hydraulic system

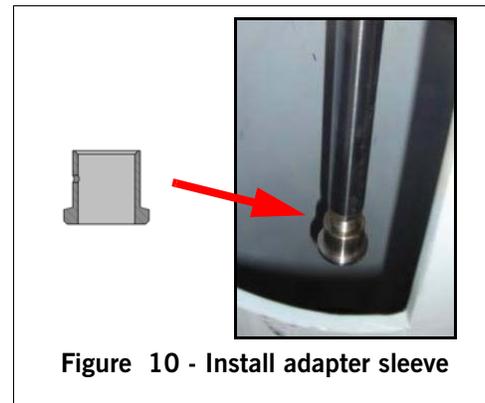
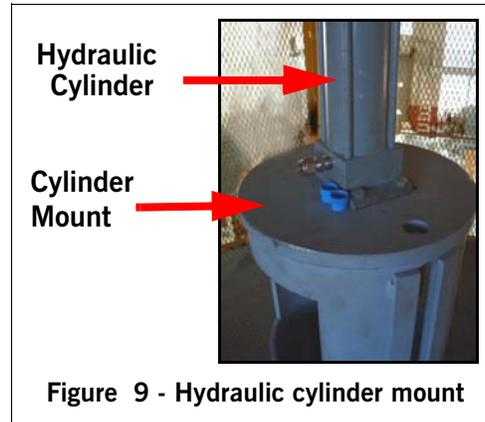
Install hydraulic lift tower assembly and hydraulic cylinder. Connect hydraulic cylinder to control rod using the supplied adapter sleeve (see Figures 9 & 10).

The hydraulic pump should be conveniently located for service access and piping run to the hydraulic cylinder.

The regulating shield is positioned by the hydraulic system. There are two hydraulic lines from the flow control valves on the hydraulic pump to the hydraulic cylinder mounted on top of the boiler. The hydraulic pump should be mounted securely with the mounting feet down. Wire the motor according to the instructions on the wiring diagram in the terminal compartment of the motor. Be sure to obtain proper rotation.

The travel speed of the regulating head is controlled by the hydraulic pump. Travel time from 0% to 100% should be about 20 seconds. To check for correct hydraulic pressure for this travel, close both flow control valves and read the hydraulic pressure gauge. The reading should not exceed 1000 psig. If necessary, correct the pressure by rotating the relief valve and adjusting. When finished, re-open the flow control valves.

Bleed the air out of the system by cracking the line fittings. Cycle the unit under no pressure until all air is removed. Keep checking the reservoir level and top off as needed. Most foreign material will flush to the reservoir after two or three days of operation. The reservoir should then be drained, the strainer cleaned, and the fluid replaced.



2.4-Electrical

Install the field power supply wiring, shown in dotted lines on the power wiring schematic. A general description of the power circuits is given in Section 4, Electrical Systems. Install all 120V control wiring, shown in dotted lines on the control wiring schematic.

Electrical installation should be in strict accord with the boiler wiring schematic, the National Electric Code, and local electrical codes. Also check all existing electrical connections in the boiler for tightness. Vibration during transit sometimes loosens these connections.

2.5-Boiler Preparation

After the circulation pump and electrodes have been installed, the boiler piped into the system, and the electrical system wired in, the boiler must be cleaned and prepared for operation.

Read Section 6, Before Startup, before starting the boiler for the first time.

2.6-First startup and checkout

When starting the boiler for the first time, the different systems must be monitored in order to test their performance. Read Section 7, Startup and Operation, before attempting to start the boiler for the first time.

POWER UNIT STARTUP

1. To properly perform the dual function of lubrication and transmission of power, we recommend the use of a good quality SAE 10 Grade Hydraulic Oil for systems having an operating temperature range from 0 deg F minimum to 160 deg F maximum, or an SAE 20 Grade Hydraulic Oil for 32 deg F Minimum to 200 deg F maximum temperature range. Operation at fluid temperature below 160 deg F is recommended to obtain maximum unit and fluid life.
2. Connect the motor to the proper electrical source, checking the motor nameplate for proper wiring of dual voltage motors. Jog the motor to check rotation. Poly-phase motors are bi-directional and proper rotation can be established by reversing any two phases.



Simultaneously energizing both solenoids on double solenoid valves will cause coil burnout.

3. System pressure should be set as low as possible to prevent unnecessary fluid heating; on some applications this setting may be from 600 to 1,000 psi as needed to overcome dynamic pressure drop or to achieve proper acceleration and lift load control components.
4. Pump noise and 'crackle' is most often caused by air entering the pump suction. The tightening of suction fittings will usually eliminate such problems. If pump fails to prime, vent pump discharge to atmosphere to establish fluid flow.
5. The fluid level should be maintained so that fluid is always visible in the sight gauge.
6. After the first few hours of operation, any foreign material from the system plumbing will be flushed to the reservoir. It is good practice to drain and replace the initial filling, and to clean the reservoir and suction strainer.
7. For most industrial applications, an operating temperature of 150 deg F is considered maximum. At higher temperatures difficulty is often experienced in maintaining reliable and consistent hydraulic control, component service life is reduced, hydraulic fluid deteriorates, and a potential danger to operating personnel is created.
8. At least once a year or every 4,000 operating hours the reservoir, suction strainer, and air vent filter should be cleaned. At this time, check the entire system for possible future difficulties. Some application or environmental conditions may dictate such maintenance be performed more frequently.

3 - Water Treatment

The KW output of the boiler is determined by the conductivity of the water in the system. Water conductivity is determined by its chemical makeup. General water hardness, pH, alkalinity, iron, oxygen, and total dissolved solids all have an effect on boiler operation. The water required for CB boilers should be non-scale forming, non-corrosive, non-foaming, and should have the following chemical characteristics:

- pH of boiler water should be between 8.5 and 11.0
- Total alkalinity of boiler water should not exceed 400 ppm
- Oxygen content of feedwater should not exceed 0.005 ppm
- Iron content of boiler water should not exceed 0.5 ppm
- Makeup water hardness should not exceed 0.5 ppm - preferably 0 ppm
- Boiler water hardness should be 0 ppm

Correct conductivity varies with the boiler voltage and temperature. This information is supplied by CB for each boiler installation. Conductivity must be high enough to allow development of the required KW output of the boiler at its designed operating pressure, and should not exceed that amount by more than 10%.



Important

In electrode steam boilers, water conductivity must be carefully controlled. If conductivity is allowed to increase without limits, it will result in damage to the boiler shell and electrodes and could also result in high voltage surface arc-over in the boiler itself.

The control of alkalinity and CO₂ content of the steam or hot water is important because these factors can affect the porcelain insulators which are used as lead-through bushings to bring the electric power into the boiler. With porcelain insulators, total alkalinity should be held below 400 ppm.

It is normally recommended that boiler water conductivity be kept as low as will enable the boiler to continue at full load operation without being unduly sluggish. Chemical additives commonly used in electrode steam boilers include sodium hydroxide, sodium sulfite, sodium sulfate, sodium tri-phosphate, and hydrazine for oxygen control. There are of course other compounds which could be used in the boiler for various purposes - for example, control of sludge fluidity. Each additive would need to be evaluated on an individual basis with attention to its effect on conductivity as well as to its intended purpose.



Caution

Any chemicals or compounds which tend to induce foaming should be avoided. Particularly in high voltage boilers, foaming will cause boiler shutdowns and could lead to serious disruptions of supply circuits and switchgear. Impurities or contaminants from elsewhere in the system should also be avoided.

 **Caution**

Before any water treatment program is implemented, a complete water analysis should be provided to Cleaver-Brooks for review.

4 - Electrical Systems

The three electrical systems are described in this section, which gives a general outline of the basic circuits and their functions. The power supply circuits (high and medium voltage) are diagrammed on the power wiring schematic in the boiler drawings, and the boiler control circuits are diagrammed on the 120V control wiring schematic.

4.1-High voltage power supply

The high voltage power supply, to be connected by the customer, is a three-phase, four-wire 'Y' connected configuration. A full sized insulated and shielded neutral is required in this circuit, as it must be of adequate capacity to take a sizeable amount of current in the case of a large phase unbalance or fault condition. This circuit must include a high voltage main circuit breaker, current transformers (one per phase for supply monitoring), and an isolating switch or mechanism, as required by the National Electrical Code and local codes which may apply. The main circuit breaker must include a common trip device which may be actuated to open the circuit breaker in response to supply circuit supervisory relays or boiler limit circuits. Potential transformers are required for voltage monitoring. The breaker must also have a normally open auxiliary contact for connection to the boiler control circuits. If the main circuit breaker is located some distance from the boiler, local codes may require the installation of a high voltage isolating switch at or near the boiler for local isolation.

Main connection

From the main circuit breaker, the four-wire voltage supply circuit is brought to the boiler by the customer and terminated at the electrodes and at the neutral lug on the boiler shell inside the electrode terminal enclosure. The ground lug is on the bottom of the casing ring. The boiler ground should have the same capacity as the supply conductors. Access to the terminal enclosures must be interlocked with the customer's main circuit breaker and/or isolating switches to prevent access to the electrodes when the power supply circuit is energized.

High voltage supply circuit supervisory relays

Proper monitoring of the high voltage supply circuit requires the use of a supervisory metering system. This system monitors signals from the supply circuit current transformers and actuates the common trip device on the customer's main circuit breaker in the event of ground fault, over-current, loss of phase, or phase unbalance.

Notice

If unbalance, ground fault, or overcurrent occurs, the supervisory relay system may also signal the limit circuit and shut the boiler down. The supervisory system is a required part of a boiler installation and must be included (either factory-installed in the boiler control panel and/or included with the customer supplied and wired high voltage switchgear)

4.2-Medium voltage power supply

Four terminals are provided for connection of the three-phase medium voltage power supply. Three terminals are for phase A, B, and C, and the control cabinet lug is for the ground. From the medium voltage terminal connections, this circuit is wired to provide power to:

- The control panel
- The circulating pump
- The hydraulic pump
- The chemical feed pump (if used)

All circuits indicated by dotted lines on the power wiring schematic must be connected in the field by the customer.

4.3-120V Boiler control circuits

The control circuits oversee the automatic functioning of the boiler during normal operation. The control circuits are briefly described in the following section as they typically appear in a standard CEJS boiler. Actual configuration may vary.

120V power supply

The primary leads of the control transformer are fused. The transformer secondary white wire is a grounded neutral, and the black wire goes through a circuit breaker switch to the boiler control circuits.

Master start/stop circuit

This circuit initiates the start signal to the boiler when the <Auto-Run> or <Test> mode is activated. The circuit also shuts the boiler off when the <Off> mode is enabled. Remote Start and Stop control is available.

High pressure limit circuit

In a high pressure condition this circuit is initiated by a signal from the high pressure limit switch (mounted on the pressure control piping). It will shut the boiler down in the high pressure condition and activate a high pressure alarm through the PLC. Manual reset of the pressure switch may be required prior to restarting the boiler.

High and low water limit circuits

If these circuits become operational, a feedwater problem is indicated; the water level has become too high. Two separate probes, located in the vessel, are used to sense water level. The High-High water probe will initiate a boiler shutdown. If either limit condition exists, the appropriate alarm ("High Water" or "High-High Water") will activate in the PLC.

Limit circuit

The limit circuit is the control function which actually gives the signal for boiler shutdown in any limit condition. For example, if the High-High Water circuit senses a High-High water condition, it will open the limit circuit.

The limit circuit is normally energized. If the circuit is interrupted by a signal from one of its ancillary limit circuits, it will stop the pump and sound the alarm. The boiler will shut down. When the alarm is cleared, this circuit will be reset.

Alarm circuit

The alarm works in tandem with the limit circuit. When a protective limit is reached, the boiler will shut down and the alarm will sound. When the <Acknowledge> button is pushed, the alarm is silenced.

High voltage feedback circuit

This circuit shows whether the high voltage circuit breaker is open or closed by lighting either the "HIGH VOLTAGE ON" or "OFF" light on the boiler control panel. It also performs an ancillary control logic function (see control wiring schematic).

Conductivity controller and control circuit

During normal boiler operation the conductivity controller will continuously sample the conductivity of the boiler water. The conductivity is sensed by the conductivity cell as the sample water passes from the sample cooler, and reads out on the conductivity transmitter in micromho/cm. Conductivity high and low are set to the desired levels. If a high or low limit is reached, the conductivity control circuit will activate the "HIGH CONDUCTIVITY" or "LOW CONDUCTIVITY" alarm in the PLC. If the high conductivity limit is reached, the circuit will also open the surface blowdown line and bleed off some water so that the water in the system can be diluted with makeup water to bring conductivity down. In a low conductivity condition, the conductivity control circuit will signal the addition of the appropriate amount of chemicals to the water in order to bring the conductivity up.

Load and pressure control circuits

These circuits handle the main load and pressure control functions, checks, and limits in the boiler. The primary logic circuits are incorporated here. Current feedback is monitored in these circuits.

A current transformer in the high voltage power circuit measures the current being drawn and feeds that information back to the load control as an indication of boiler power drawn. If the system demand for steam is higher than output, an instruction is sent to the control circuit to lower the regulating shield for the output needed. If a lower output is required, the load control raises the regulating shield for the lower demand.

The load control also allows the circulating pump and load control system to be tested with the high voltage power off. On the boiler control panel, the "Test" function allows the load control to drive the regulating shield to its minimum position and permits the circulating pump to be activated. The regulating shield can then be manually moved to the maximum load position. If the pump and load control system are functioning properly, the test is complete and mode may be returned to 'Auto-Run'.

Standby control circuit

This circuit will place the boiler in Standby mode. The regulating shield will drive to minimum load position and the circulating pump will stop. The "STANDBY" banner on the boiler touch screen will come on, as will the standby heater (if present). The regulating shield will stay in the minimum load position as long as the boiler is in standby. This circuit uses the control pressure transmitter and is set at the desired standby pressure.

Circulating pump control circuit

If the boiler is ready for operation and placed into 'Test' or 'Auto-Run' mode, this circuit supplies power to the circulating pump.

Hydraulic system control circuit

This circuit is controlled by the load control and is directly responsive to system steam demand. When the signal for more steam is given, the PLC energizes the hydraulic solenoid valve to drive the regulating shield to a position which allows more water flow to the electrodes.

When steam production and demand are balanced, the hydraulic solenoid valve is de-energized. When less steam is required, the hydraulic pump is started and the solenoid valve is energized to drive the regulating shield to a position allowing less water flow to the electrodes. Time delays are used in these circuits to prevent cycling of the pump motor starter.

5 - Water Level Control Systems

CB electrode high voltage steam boilers are designed to operate with constant water levels. During operation, feedwater must be added to compensate for steam production and surface blowdown. A modulating valve is used to admit feedwater to the boiler in proportion to the rate of water consumption. The feedwater control system may consist of one, two, or three elements depending upon the degree of instrumentation desired and/or the nature of the steam load.

Single element (water level only)

For most CB applications a single element (water level only) control system is satisfactory. The water level transmitter on the water column senses water level deviation from the set point and modulates the feedwater valve in order to match feedwater flow to actual water consumption. By proportioning feedwater flow to water level deviation from set point, this deviation is reduced and water level is maintained.

Two element (water level and steam flow)

When steam requirements are very irregular and involve large and/or rapid changes in boiler steaming, a multiple element feedwater control system may be needed.

The two element system uses both water level and steam flow signals to position the feedwater control valve. The water level transmitter measures level deviation from the set point. The steam flow transmitter measures the rate of steam flow. Feedwater flow is adjusted to compensate both for level deviation and for changes in rate of steam flow.

Three element (water level, steam flow, and water flow)

If the boiler is large and steam requirements fluctuate widely and rapidly, a three element feedwater control system may be used to provide smoother control than would be obtainable with a two element system.

The three element system uses feedwater flow rate as well as steam flow and water level signals to modulate the feedwater control valve. The water flow and steam flow signals are integrated to assure that water flow fluctuations are no more severe than actual steam flow fluctuations as feedwater flow is varied to compensate for water level deviation and changes in rate of steam flow.

6 - Before Startup

6.1-Boiler Cleanout

General - Before first startup, inspect the entire boiler for loose objects (metal scraps, dust, dirt, paper, etc.) which may have accumulated during construction or shipping. Check also for wetness, moisture, or rust on the electrode circuitry. The boiler must be thoroughly clean and dry before startup. The entire system must be cleaned and flushed to remove fabrication oil, welding slag, piping compounds, sand or clays from the jobsite, etc.

Rinsing out - Clean bottom of vessel and remove pump inlet plug. Verify condition of all manholes and ports.

Boiler must be thoroughly rinsed three times to remove all contaminants prior to conducting a water test. Rinse once with 80 deg C water and twice with cold water.

 **Important**

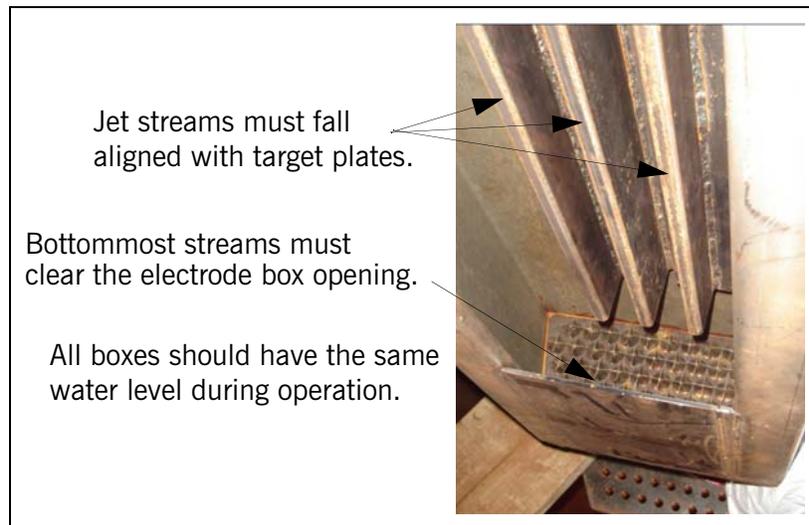
CB will not be responsible for damage incurred at startup unless the preceding precautions are taken.

6.2-Water Test

Verify correct positioning and alignment of jets by running the circulation pump and observing jet shapes. Check for excessive splashing at the top of stroke; optional splash guards may be installed. Eliminate any leaks or spraying.

Check for clogged nozzles. ALL nozzles must flow.

Coordinate incremental skirt lowering with workers outside boiler while monitoring jets.



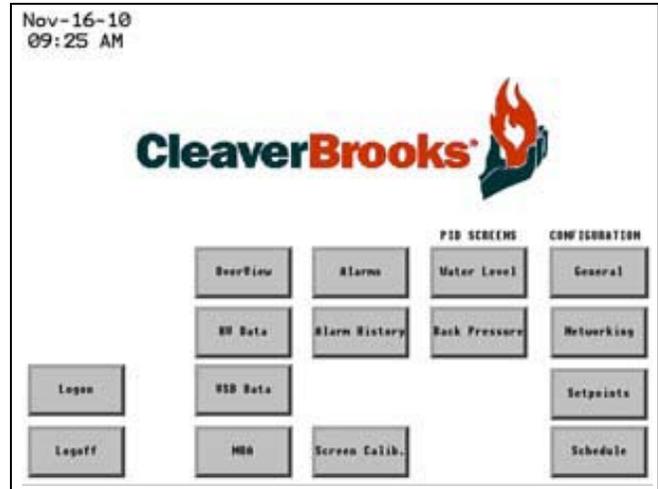
During water test, record pressure reading at pump inlet and outlet. Compare DP to specified value. Before Startup, run a water level high limit check.

7 - Boiler Controls

CEJS boilers feature an integral control panel housing the PLC -based control system components and the touchscreen HMI. The HMI screens are described below.

7.1- Main Menu

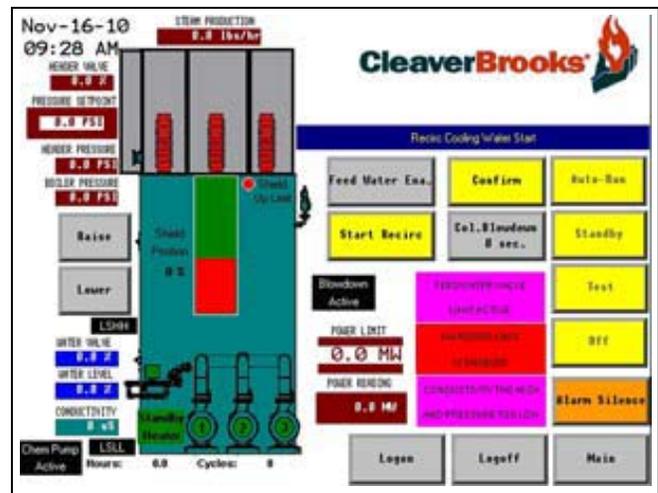
The **Main Menu** appears on power-up. This screen allows user login for access to password-protected features and serves to navigate to other control screens.



7.2-Overview

The **Overview** screen monitors critical data during boiler operation, and is the primary control screen for commissioning and starting up the boiler. This screen contains operating controls, status messages, and transmitter data including a graphic/ numeric indicator to show control shield position and numeric displays for:

- Steam pressure and water level
- Steam header valve and water valve position
- Water conductivity
- Power output to the electrodes
- Power limit
- Steam Production

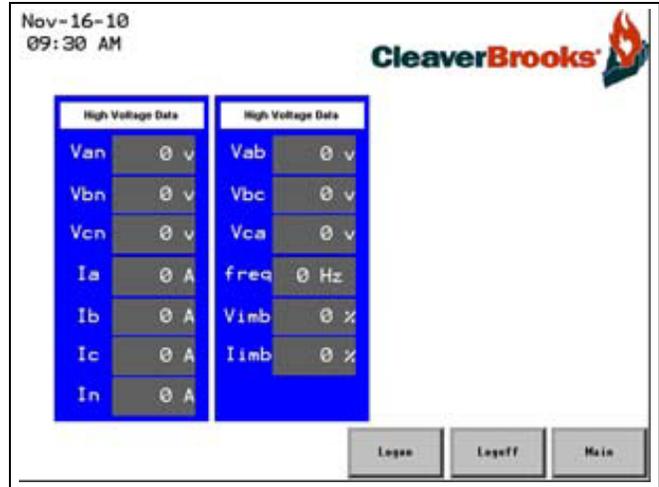


In "Test" mode, the position of the shield can be adjusted by pressing the "Raise" button to elevate and the "Lower" button to descend. The "Col. Blowdown" button allows the user to set a timer to inhibit the low level alarm while a column blowdown is being performed. Other on-screen indicators are as follows:

- Feedwater Valve Limit Active - Indicates that the pressure setting to limit the feedwater valve position is enabled. See Operating Setpoints, Press to Limit FW Vlv%, or Software Switch Setpoints, PSL settings for more details.
- MH Power Limit Is Enabled - Indicates that the Power Limit setpoint on the Operating Setpoints screen has been enabled.
- Conductivity Too High and Pressure Too Low - Indicates that the conductivity level is too high in comparison to the pressure level of the boiler. The conductivity level is below the lower limit for start-up. See Software Switch Setpoints, CSL setting for more details.

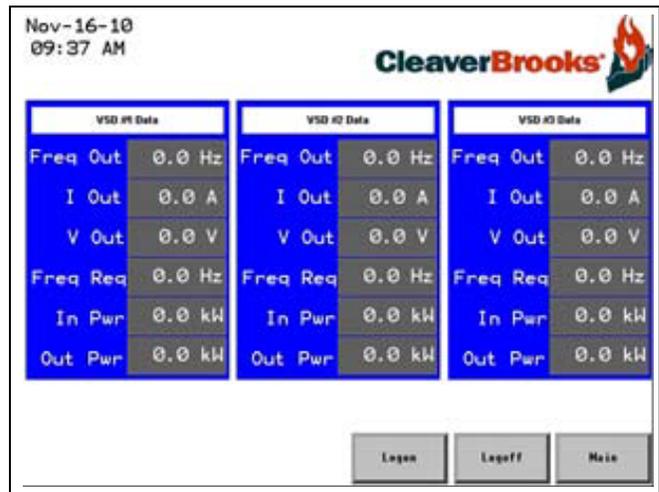
7.3-HV Data

The **HV Data** screen monitors the boiler's 3-phase high voltage power via the power meter. This screen shows the real-time voltages and currents for each phase (including current to neutral) along with the frequency and voltage/current imbalances.



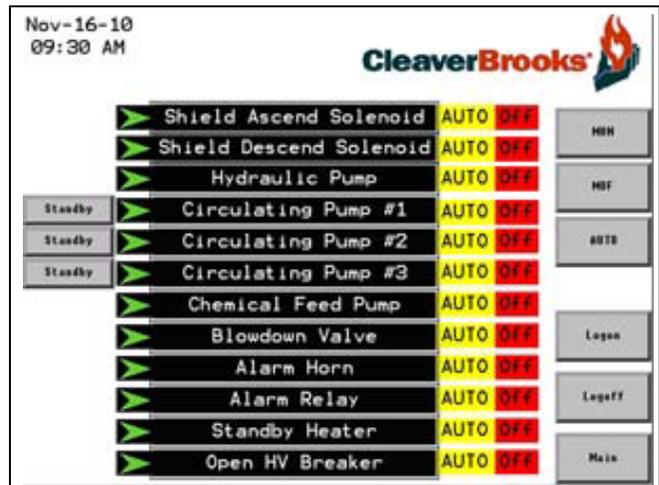
7.4-VSD Data

The **VSD Data** screen monitors the status of each circulation pump variable speed drives as required. This screen displays the output voltage, current, and frequency. Also shown is the input and output power in kilowatts.



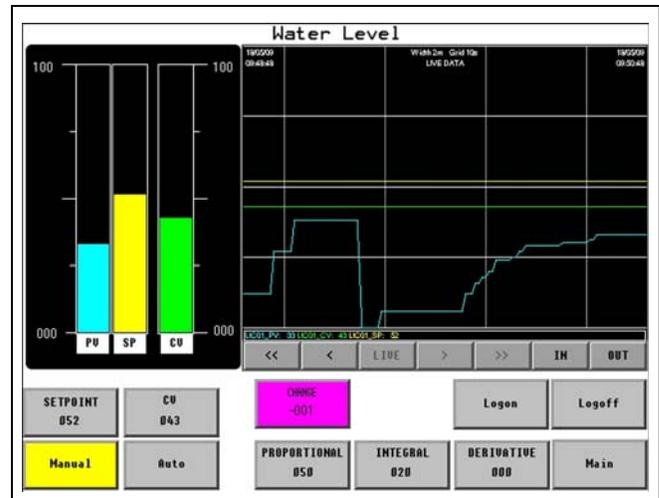
7.5-MOA

The **MOA (Manual/Auto)** screen allows all boiler control devices with digital outputs to be placed under manual control and provides on/off and auto/manual status for all digital points. Selections include MON (Manual On), MOF (Manual Off), or AUTO. This screen can also be used to select the standby pump, if applicable. Pressing the Standby button places the corresponding active pump in standby mode. This in return moves the former standby pump into active position. This screen also allows the operator to monitor the status of each device during startup or while troubleshooting.



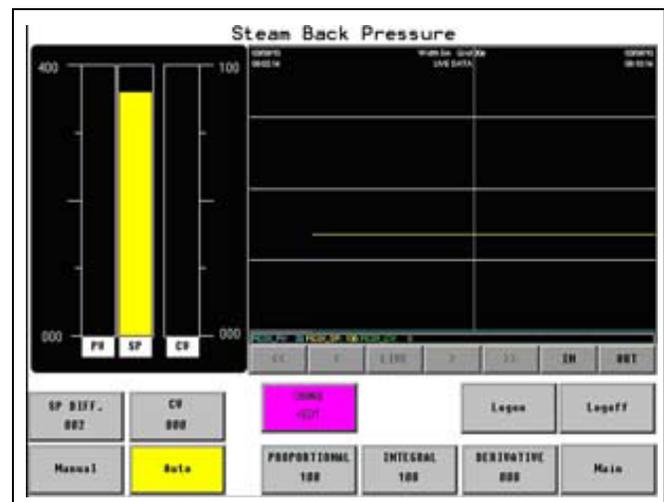
7.6-Water Level PID

The **Water Level PID** screen allows for the setting of the system setpoints controlling Proportional, Integral, and Derivative values (password-protected). The user must be logged in to access the Manual operations. While in manual mode, the user can use the "CV" button to enter a value for the PID loop output to manually control the valve. This screen allows for PID control of water level control valve including loop tuning and setpoint entry with manual override for loop control. This screen monitors the process variable, setpoint, and control output in a bar graph and in a real-time trending window.



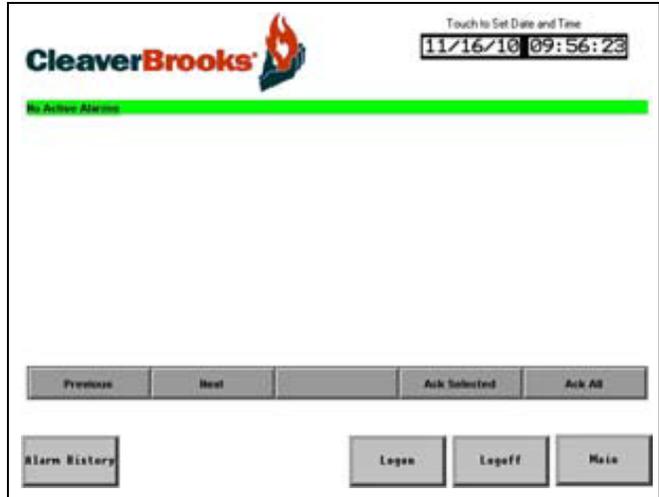
7.7-Back Pressure PID

The **Back Pressure PID** screen allows for the setting of the system setpoints controlling Proportional, Integral, and Derivative values (password-protected). The user must be logged in to access the Manual operations. While in manual mode, the user can use the "CV" button to enter a value for the PID loop output to manually control the valve. This screen allows for PID control of the back-pressure valve and allows loop tuning and setpoint entry with manual override for loop control. The setpoint is entered as a differential from the operating pressure of the boiler. This screen monitors the process variable, setpoint, and control output in a bar graph and in a real-time trending window.



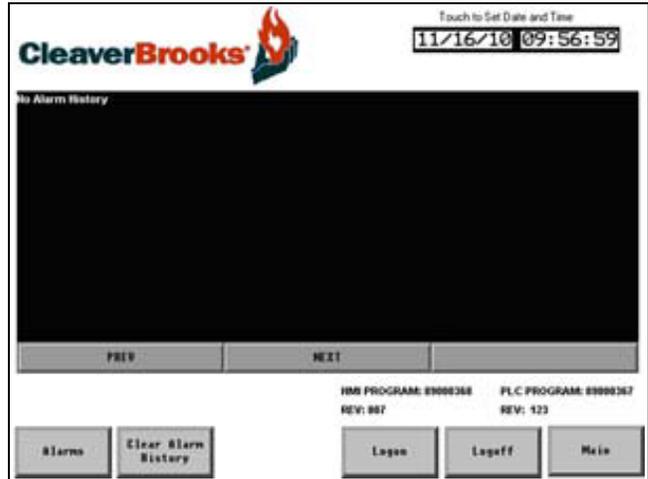
7.8-Alarm

The **Alarm** screen is used to acknowledge alarms. Once acknowledged, an alarm may be cleared from the Alarm History screen. When acknowledging an alarm, investigate and correct the cause of the alarm before re-starting the boiler.



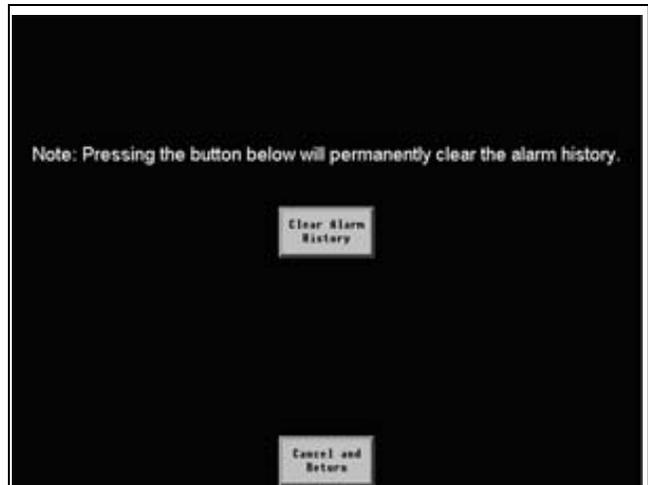
7.9-Alarm History

The **Alarm History** screen displays a record of alarms logged by the system with a date/time stamp and brief description for each. From this screen, the user can advance to Clear Alarm History screen to remove all previous alarm notifications. The user must be logged on to clear the alarm history.



Clear Alarm History

The **Clear Alarm History** screen is used to permanently delete the alarm history once an acknowledgement of the alarms has been selected from the Alarm screen.



7.10-General Configuration

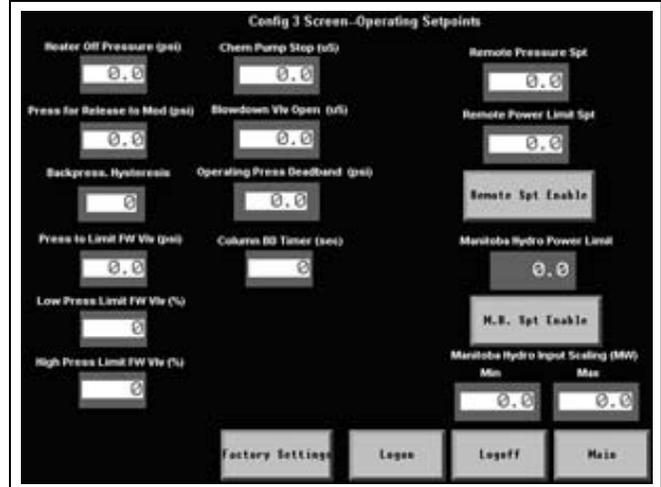
The **General Configuration** screen contains general information about the boiler in addition to contact information for the local Cleaver Brooks representative. The user must be logged on to change these values.

7.11-Networking Configuration

The **Networking** configuration screen allows the user to set the IP address for the HMI and allows for the option of automatic alarm notifications via e-mail. The user must be logged on to modify these values.

7.12-Operating Setpoints Configuration

The **Operating Setpoints** configuration screen allows the user to enter specific setpoints for normal boiler operations. The remote pressure and power limit setpoints as well as the power limit and scaling factors can be set/enabled from this screen. These operating setpoints are typically determined at startup. The user must be logged on to modify operating setpoints. Factory Settings can be accessed from this screen.



The following is a descriptive list of the operating setpoint variables:

- Heater Off Pressure (psi)
 - Defines the pressure setting at which the back-up heating elements turn-off.
- Press for Release to Mod (psi)
 - Defines the pressure setting to allow the shield to modulate and control to setpoint after start-up. Until this setpoint is reached, the shield ramp is moved incrementally based on the setpoints on the Factory Settings screen. This setpoint is duplicated on the Software Switch Settings (Soft Switch SPs) screen as the PSL setting.
- Backpress. Hysteresis
 - Defines the value at which the back-pressure valve begins to modulate into a closed position. The valve starts closing when the pressure drops below the setpoint value minus the "Backpress. Hysteresis" value. This creates a deadband/buffer zone for the modulated closing of the valve.
- Press to Limit FW Vlv (psi)
 - Defines the pressure setting that limits the feedwater valve position during start-up. This setpoint is duplicated on the Software Switch Settings (Soft Switch Sps) screen as the PSL setting. When the boiler pressure is below this set point, the travel of the feed water valve is limited to the High Press Limit FW Vlv (psi) setpoint value on the Operating Setpoints screen.
- Low Press Limit FW Vlv (%)
 - Defines the percentage in which the feedwater valve is opened when the boiler pressure is below the feedwater valve pressure limit setting.
- High Press Limit FW Vlv (%)
 - Defines the percentage in which the feedwater valve is opened when the boiler pressure is above the feedwater valve pressure limit setting.
- Chem Pump Stop (s)
 - Defines the upper conductivity limit at which the chemical pump stops supplying chemicals to the system.
- Blowdown Vlv Open (s)
 - Defines the upper conductivity limit at which the blowdown valve opens to purge the system.

- Operating Press Deadband (psi)
Defines the deadband range (psi) to eliminate shield "hunting" when the pressure does not exactly match the operating pressure setpoint.
- Column BD Timer (sec)
Defines the time that the level alarms and associated feedback are disabled during a blowdown sequence.

7.12a - Factory Settings Warning

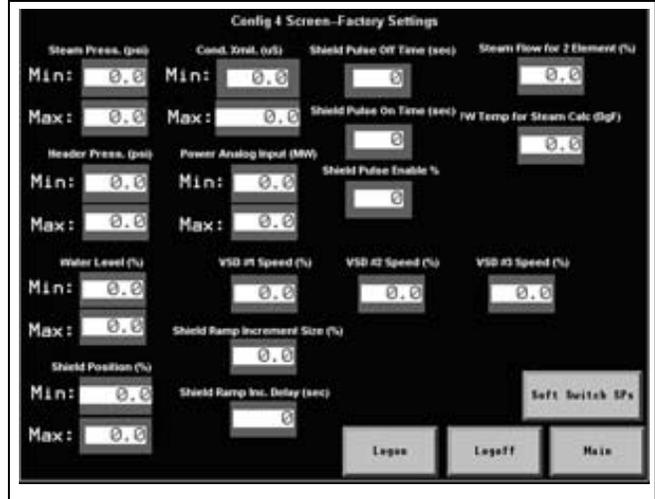
The **Warning** screen appears when attempting to access the Factory Settings screen. The user should select "Continue" only if the operator is qualified and authorized to make changes to these parameters. The user must be logged on to access and modify the factory settings.



7.12b - Factory Settings

The **Factory Settings** configuration screen allows the setting of crucial setpoints during the initial startup of the boiler. These setpoints are typically determined at startup and are not changed in the normal course of boiler operation. These parameters are set by Cleaver Brooks and should only be changed by qualified and authorized personnel. The user must be logged on to modify these factory setpoints. This screen is accessed from the Operating Setpoints configuration screen. Software Switch SetPoints (Soft Switch SPs) can be accessed from the Factory Settings screen.

The following is a descriptive list of the factory setpoint variables:



- Steam Press. (psi)
Defines the scaled range for the steam pressure values of the system.
- Header Press. (psi)
Defines the scaled range for the header pressure values of the system.
- Water Level (%)
Defines the scaled range for the water level of the system.
- Shield Position (%)
Defines the scaled range for the shield position transmitter from "Full-Down" to "Full-Up" position of the shield.
- Cond. Xmit. (s)
Defines the conductivity range for the conductivity transmitter.
- Power Analog Input (MW)
Defines the scaled range of the analog power input in megawatts (MW).
- VSD #1/#2/#3 Speed (%)
Defines the scaled speed of each of the pump VSDs.
- Shield Ramp Increment Size (%)
Defines the percentage-based increment at which the shield travels during start-up mode when the boiler pressure is below the "Press for Release to Mod (psi)" setpoint located on the Operating Setpoints screen.
- Shield Ramp Inc. Delay (sec)
Defines the time delay before moving to the next shield increment during start-up mode when the boiler pressure is below the "Press for Release to Mod (psi)" setpoint located on the Operating Setpoints screen.

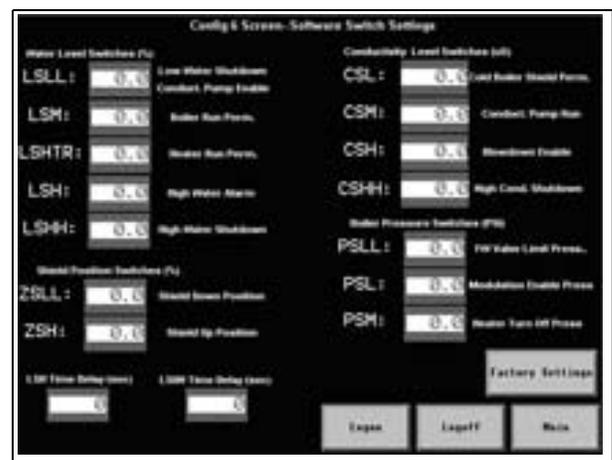
- **Shield Pulse Off Time (sec)**
Defines the amount of time the hydraulic shield contactor remains de-energized (Off) during the shield pulse.
- **Shield Pulse On Time (sec)**
Defines the amount of time the hydraulic shield contactor remains energized (On) during the shield pulse.
- **Shield Pulse Enable (%)**
Defines the percentage of the MW limit in which to enable the shield to begin pulsing. Shield pulsing allows for fine tuning as the boiler nears the set MW limit. Setting this value to 0% always enables the shield to pulse. Setting this value to 100% never enables the shield to pulse.

Example: If the output limit is set to 10 MW and the Shield Pulse Enable% setpoint is established to be 90%, then the shield pulse will be enabled at 9 MW output.
- **Steam Flow for 2 Element (%)**
Defines the steam flow output percentage limit at which the two element feedwater system is enabled. The two element feedwater system is based on the water level and calculated steam output determined from the MW reading.
- **FW Temp for Steam Calc (DgF)**
Defines the temperature value (degrees Fahrenheit) used to calculate steam flow based on the current MW reading of the boiler. This value is used when there is no temperature input to the system.

7.12c - Software Switch SetPoints

The **Software Switch SetPoints** (Soft Switch SPs) screen allows the user to adjust the setpoints for the various transmitter driven functions of the boiler. These parameters are set by Cleaver Brooks and should only be changed by qualified and authorized personnel. The user must be logged on to modify these factory setpoints. This screen is accessed from the Factory Settings screen.

The following is a descriptive list of the software switch setpoint variables:



- **Water Level Switches (%)**
LSLL: Low water limit which triggers the low water boiler shutdown.
LSM: Median water limit which allows the boiler to start-up after this level is achieved.
LSHTR: Low water limit which disables the operation of the heater when the water level drops below this setpoint.

- Water Level Switches (%) (cont.)

LSH: High water limit which triggers the high water alarm.

LSHH: High-High water limit which triggers the high water boiler shutdown and opening of the HW breaker.

- LSH Time Delay (sec)

Defines the amount of time delay between the triggering of the high water limit (LSH) and the sounding of the high water alarm to alleviate momentary or nuisance trips.

- LSHH Time Delay (sec)

Defines the amount of time delay between the triggering of the high-high water limit (LSHH) and the shutdown of the boiler to alleviate momentary or nuisance trips.

- Shield Position Switches (%)

ZSLL: Setpoint which limits the "Full-Down" position of the shield during normal boiler operation.

ZSH: Setpoint which limits the "Full-Up" position of the shield during normal boiler operation.

- Conductivity Level Switches (s)

CSL: Low conductivity limit which defines the conductivity threshold level that will allow the shield to lower and the boiler to operate during cold start-up.

CSM: Median conductivity setpoint which enables/disables the chemical feed pump. When the boiler is running, the chemical feed pump will be enabled when the conductivity level is below this setpoint and disabled when the conductivity level is above this setpoint.

CSH: High conductivity limit which triggers the automatic blowdown valve to open.

CSHH: High-High conductivity limit which triggers an automatic boiler shutdown.

- Boiler Pressure Switches (psi)

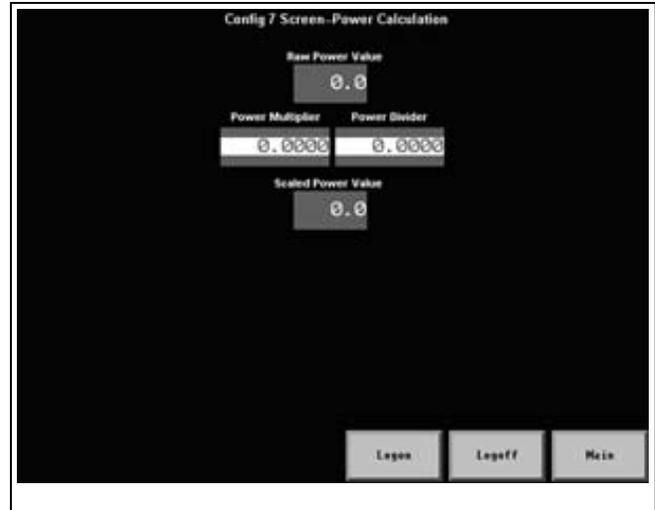
PSLL: Defines the pressure setting that limits the feedwater valve position. This setpoint is duplicated on the Operating Setpoints screen as the Press to Limit FW Vlv (psi) setting. When the boiler pressure is below this set point, the travel of the feed water valve is limited to the High Press Limit FW Vlv (psi) setpoint value on the Operating Setpoints screen.

PSL: Defines the pressure setting to allow the shield to modulate and control to setpoint after start-up. Until this setpoint is reached, the shield ramp is moved incrementally based on the setpoints on the Factory Settings screen. This setpoint is duplicated on the Operating Setpoints screen as the Press to Release to Mod (psi) setting.

PSM: Pressure limit which disables the heater when this pressure setpoint is achieved in standby mode only.

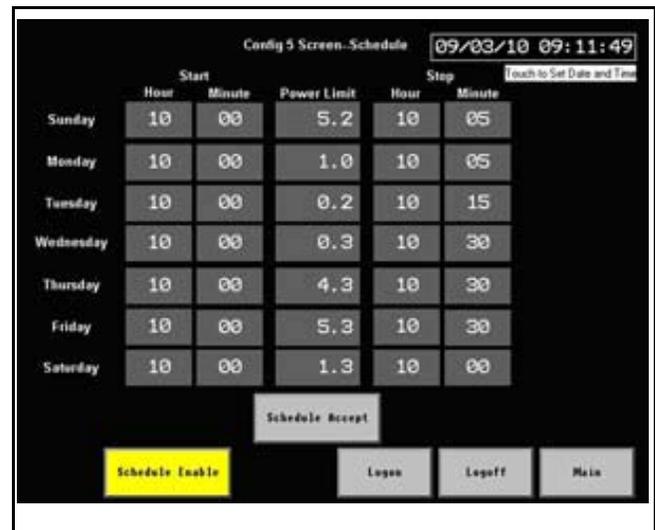
7.12d - Power Calculation

The **Power Calculation** screen allows for the scaling of the raw power reading from the power meter by adjusting scaling parameters to produce the desired scaled power value. These parameters are set by Cleaver Brooks and should only be changed by qualified and authorized personnel. The user must be logged on to modify these factory setpoints. This screen is accessed by pressing a "hidden" button located in the top right-hand corner of the **Software Switch Settings** screen.



7.13-Schedule

The **Schedule** configuration screen allows the user to program the boiler's daily start and stop times along with a power limit for individual days. This seven day schedule is repeated as a weekly schedule.



8 - Startup and Operation

When starting the CEJS boiler for the first time, observe the deaerator or condensate tank, sight glass, and chemical feed pump to monitor their performance until the control systems have been tested. After the pressure is up for the first time, check the safety valve operation and settings. The boiler pressure should be at least 75% of the safety valve setting when the test handles are lifted. The valve should be allowed to snap shut to assure a good seat. **Note: Boiler should not be heated/cooled quicker than 3-5 °F per minute to protect the porcelain insulators and glass tubes.**

8.1-Prestart

1. Open the following valves: Feedwater, Conductivity Sample, Steam Outlet, Manual Air Vent, Chemical Feed, and Cooling Water to the circulating pump (if applicable).
2. Close the following valves: Water Column Blowdown and Feedwater Bypass Valve
3. Adjust pressure setpoint in PLC. Pressure switches are set as shown on control schematic
4. Open the high voltage switchgear.
5. Inside the control cabinet, check fuses and close the circuit breaker for the medium voltage circuits, the pump, and the hydraulic system motors.
6. Go to the Overview screen on the HMI. Enable "Test" mode.
7. Press <Feed Water Enable> at the HMI. Start the feedwater pump and fill the boiler with water. The water should stop automatically when it reaches the right level.
8. Once the water level reaches the set-point and the regulating shield has driven to the no load position, the shield position indicator should be at 100% and the circulating pump should start.
9. Manually adjust the regulating shield downward and upward. Return to "Auto-Run" when movement goes freely to both stops and speed of movement has been adjusted.
10. Adjust the sample flow and cooling water flow. Allow the conductivity sample to stabilize. If necessary, increase the conductivity by allowing chemicals to be pumped into the boiler. Conductivity for startup should not exceed 100 to 800 μS .

8.2-Startup (Manual Mode)

Note: "Automatic Mode" is recommended for typical startup. "Manual Mode" should only be used in limited circumstances. Cleaver-Brooks recommends using "Manual Mode" operation during initial startup of boiler to ensure proper functionality of controls and integration with system.

1. Raise the shield to the 'No Load' position.
2. Close the high voltage switchgear.
3. Enable "TEST" Mode. Press <Feed Water Enable>. Select <Start Recirculation>..
5. Manually monitor conductivity pump. A maximum conductivity of 600 S should be allowed. The conductivity pump can be manually turned on and off from the "MOA" screen.

6. Lower shield at a maximum rate of 5% increments approximately every 5 minutes. Continue this process until the boiler pressure reaches 100 psig. When the steam pressure reaches 40 psi, close the manual air vent. The boiler pressure will need to exceed the level required to open the back pressure valve, and be slightly above the pressure in the steam main, before the boiler will begin to feed steam into the system. Adjust the back pressure valve control set point until the desired back pressure is maintained, and the passage of steam into the system will begin.

7. Check the boiler steam pressure gauge. Generally, there will only be a negligible pressure drop through the back pressure valve.

8. Enable "AUTO-RUN" mode.

9. Adjust "Power Limit" setting to the desired output. The boiler is now in operation and is free to modulate as required.

8.3-Startup (Automatic Mode)

1. Raise the shield to the 'No Load' position.

2. Close the high voltage switchgear.

3. Enable "AUTO RUN" mode.

4. The circulating pump will start and the regulating shield will go to the full-load position. Allow the boiler to heat up and begin to make steam. When boiler steam pressure reaches 40 psi, close the manual air vent. The boiler pressure will need to exceed the level required to open the back pressure valve, and be slightly above the pressure in the steam main, before the boiler will begin to feed steam into the system. Adjust the back pressure valve control set point until the desired back pressure is maintained, and the passage of steam into the system will begin.

5. Check the boiler steam pressure gauge. Generally, there will only be a negligible pressure drop through the back pressure valve.

6. Adjust "Power Limit" setting to the desired output. The boiler is now in operation and is free to modulate as required.

8.4-Emergency shutdown

1. Push the large red "STOP" button on the boiler control panel. The boiler will go to OFF mode and the circulating pump will stop. The regulating shield will stay in the position it was in when the STOP button was pushed. The high voltage switchgear will be opened when the emergency stop is pushed.

2. To restart the boiler after an emergency shutdown, ensure the stop button is returned to the operating position and follow the normal startup procedure outlined in Section 7.2 above.

8.5-Standby and shutdown

Standby

Enable "STANDBY" mode. The regulating shield will drive to the no-load position and the Standby banner will turn yellow. The circulation pump will stop and the standby heater (if included) will energize to keep the boiler hot.

Shutdown

Enable "OFF" mode. The regulating shield will move to the no-load position and the circulating pump will stop. The PLC may be turned off using the control power switch on the panel.

8.6-Normal operation

The CEJS boiler has completely automatic operating controls, feedback, and limiting functions. The only attention it will need during normal operation is a periodic check of the ammeter. The "POWER LIMIT" may be adjusted at any time.

8.7-List of Alarms

The following is a full list of alarm codes/names with corresponding descriptions of each.

ALM001 Water Level High High (Probe) - High High Water Probe or LSHH in Software. Shuts down the boiler and opens HV breaker.

ALM002 Water Level High (Probe) - High Water Probe or LSH in Software.

ALM003 VSD#1 Fault - VSD fault switches operation to standby pump. If standby pump is not available, a VSD fault shuts down boiler.

ALM004 Modbus Comms Fault - Comms loss to Nexus for 30 seconds.

ALM005 E-Stop Pressed - Shuts down boiler & opens HV breaker.

ALM006 Hydraulic Pump Fault - Aux. contacts on hydraulic pump contactor are not functioning properly.

ALM007 Shield Down Position Fault - Down solenoid on for 120 seconds, shield position not down.

ALM008 Shield Up Position Fault - Up solenoid on for 120 seconds, shield position not up.

ALM009 Low Low Water Fault - Shuts down boiler.

ALM010 Boiler Pressure High High - Input slot 2, channel 1. Pressure input shuts down boiler.

ALM011 HV Breaker Control Power Loss - Input slot 2, channel 10. Control power is Off on HV breaker.

ALM012 N/A

ALM013 Device in Manual Override Mode - At least one (1) device on MOA screen is in manual mode.

ALM014 Phase Imbalance Fault - 10% or greater phase imbalance for 10 seconds.

ALM015 Current Imbalance Fault - 10% or greater current imbalance for 10 seconds.

ALM016 Analog Input Limit Failure - One of the analog inputs is out of range.

ALM017 High Voltage Breaker Open - Slot 2, channel 5 input loss. Alarms only when boiler is in operation.

ALM018 High Voltage Safety Contact Fault - Slot 2, channel 4 input. Safety Contact in HV breaker tripped.

ALM019 N/A

ALM020 Boiler Pressure High - Slot 2, channel 12 input.

ALM021 VSD# 2 Fault - See ALM003 VSD#1 Fault above for more details.

ALM022 VSD# 3 Fault - See ALM003 VSD#1 Falut above for more details.

ALM023 High Conductivity - CSHH in Software - Raises shield.

ALM024 Water Level High High (Transmitter) - High High Water Transmitter or LSHH in Software. Shuts down the boiler & opens HV breaker.

ALM025 Water Level High (Transmitter) - High Water Transmitter or LSH in Software.

9 - Maintenance

Since the boiler's operation is usually supervised by its automatic controls, conscientious preventative maintenance should be practiced at all times. Keep the electrical circuitry clean and dry, and all contacts tight, especially on the magnetic contactors. Do not allow dust or dampness to accumulate anywhere in the control cabinet. Do not allow the temperature in the control cabinet to exceed 120 deg F. Watch for irregularities in operation and try to catch developing problems early. Perform the periodic maintenance listed in the following sections at the times given.

 **Important**

Allow only qualified personnel to do maintenance work on this equipment.

9.1-Shift maintenance

1. At some point during each shift, the gauge glass on the water column must be blown down to clear out any accumulated sediment. Blowdown should be performed during boiler operation.

Gauge glass blowdown

- A. Close both top and bottom valves to the gauge fully. B. Open the drain valve on the bottom of the gauge glass.
- C. Open the top valve just enough to lift the disk from its seat, but not enough to cause the ball check inside the valve to seat.
- D. At this point, live steam will be blowing down through the gauge glass and out the drain. Let blowdown continue for a few seconds (until it becomes apparent that all sediment has been dislodged from the glass), then fully close the top valve.
- E. Close the bottom gauge glass drain.
- F. Open the top valve again, just enough to allow a slow passage of pressure. When the flow stops, open this valve fully.
- G. Open the bottom valve to the glass (not the drain) just enough to allow a slow passage of water into the glass.
- H. Let the seepage continue until the water level stabilizes, then slowly open this valve fully.

The above procedure assures a true reading of the gauge glass with both top and bottom valves open. It is important to make sure that the ball checks in the valves to the gauge glass do not accidentally seat. If a ball check seats, the gauge glass will no longer reflect the true water volume.

If the boiler shuts down on a high or low water limit and the gauge glass level and all other conditions are normal, one or both of these ball checks has seated or one of the lines to the gauge glass has clogged.

2. Blow down the gauge glass of the condensate return tank.
3. Check all hand-operated valves for packing leaks. Check to see that the boiler blowdown, air vent, condensate tank feed, and drain valves are closed and all others are open.
4. Check the regulating shield travel for responsiveness to hydraulic pump direction change. If it is sluggish or unstable, correct the hydraulic pressure.
5. Check to see if the desired pressure is being maintained in the system and boiler.

9.2-Daily maintenance

- 1.Clean the strainers in the water supply, cooling, feedwater pump, and blowdown cooling lines.
- 2.Check each open valve for freedom of operation.
- 3.Blow down the water column by opening the drain on the bottom. Allow two to ten seconds for blow-down, then close the valve fully.
- 4.Blow down the boiler to clear out any sludge accumulation in the pressure vessel. Generally, five to ten seconds will be sufficient. Experience and observation will indicate the proper duration of blow-down. The color of the water is a good indicator of the amount of accumulated sludge. The murkier the water is, the longer blowdown should continue or the more often the boiler should be blown down.

Boiler blowdown

- A.Open the blowdown valve nearest the boiler, fully.
 - B.Open the second valve as quickly as possible to minimize valve seat erosion.
 - C.The boiler will be blowing down at this point. When blowdown has continued long enough, fully close the valve furthest from the boiler.
 - D.When the flow stops, close the nearest valve to ensure a tight shutoff.
-
- 5.Check the levels in the chemical feed and hydraulic fluid reservoirs and top off as needed. If the hydraulic fluid level is abnormally low, check the hydraulic system for leaks.
 - 6.Check for steam leaks at the electrode insulators and the control rod packing. If necessary, replace gaskets and/or packing. Refer to Section 9.6 for more information on the packing of the gland housing for the control rod. Control rod packing should be checked for leaks within 2-4 weeks of initial operation after the gland is packed.
 - 7.Check mechanical seal on circulating pump for significant leakage.

9.3-Monthly maintenance

- 1.Shut the boiler down and turn off the power supply. Check all electrical connections for tightness. Be particularly careful during the first few months of service. Check contacts for discoloration, corrosion, or pitting.
- 2.Make an instantaneous check of the safety valves. Allow them to slam shut to ensure good seating.
- 3.Check the elements of the standby heater with a megohmmeter. Test the lead wire to ground. A reading of 25000 ohms or more is satisfactory. Below 25000 ohms indicates a defective element, which should be replaced at the next scheduled boiler annual inspection.

Standby heater replacement

- A.Sketch the wiring hookup of the element head and busses. Identify each wire.
 - B.Disconnect the wire and remove the element flange bolts. A tapped hole is provided to assist in breaking the gasket free.
 - C.Pull the flange and element bundle straight out. Handle the element gently.
 - D.Remove the faulty element from bundle. Replace with a new element and ferrule.
 - E.Re-insert element bundle and install with a new gasket and seal. Torque the bolts to 115ft-lb. Re-wire the elements and busses according to sketch made at beginning
- 4.The air supply filters (if present) on the feedwater controller and back pressure regulating valve should be removed and cleaned on a regular basis. Experience will determine the maintenance interval. It is recommended to periodically remove any condensate in the bowl of the regulator.
 - 5.Check the conductivity cell. Abnormal conductivity readings usually indicate that the cell needs cleaning or replatinization. If there are any foreign substances on the cell (oil, grease, rust, sediment, etc.) it must be cleaned. Do not scrape or clean mechanically, as this may remove the coating. The cell should be dipped into a solution of 10% hydrochloric acid in water and left to soak for five to ten minutes, as needed. Afterwards, rinse thoroughly in running tap water.
 - 6.Check the entire piping system for leaks.
 - 7.Check the boiler auxiliary equipment.

9.4-Annual maintenance

- 1.Shut the boiler down, drain the water from the system, and clean out all accumulated scale buildup, corrosion, and sludge from the pressure vessel.
- 2.Check for electrode deterioration and erosion of the electrodes, counter electrodes, and stripper of the regulating shield.
- 3.Check for erosion of nozzles. Check the nozzle stock for erosion and remove any scale buildup.
- 4.Check the general mechanical condition of the boiler assembly, paying particular attention to the regulating shield operating equipment.
- 5.Check all pressure gauges for accuracy.
- 6.Remove the circulating pump(s) and inspect for wear of the shaft bearings and pump impeller.
- 7.Have an approved safety valve service agency check the safety valves for wear and correct settings.
- 8.Inspect the blowdown valves for seat erosion.
- 9.Clean the hydraulic pump reservoir, air filter, and suction strainer.

9.5-Replacement of porcelain insulators

1. Turn off all power to the boiler, drain the pressure vessel completely, and allow it to cool. Boiler should not be heated/cooled quicker than 3-5 F per minute to protect the porcelain insulators from damage.
2. Securely support the electrode box inside the vessel. Remove the high voltage cable(s) and loosen the electrode rod nut. Remove the rod assembly carefully, taking care not to crack or chip the insulators or damage the assembly in any way (details in the following pages).
3. Clean and inspect the Pyrex tube for cracks and replace if necessary.
4. Replace the damaged porcelain insulator and reassemble the electrode with new gaskets.
5. Replace the electrode in the boiler and reinstall the shield and the electrode plate and housing inside the vessel, again taking care not to damage the electrode. Check the clearances and dimensions for the assembly against the boiler drawings to ensure that the electrode has been positioned properly. Tighten the electrode rod nut to 500 ft-lb, making sure the rod does not rotate. See Figures 11 and 12 for electrode components and order of assembly.

 **Caution**

Take extreme care when handling electrode components. Use gloves when handling.

Prior to re-assembly, clean all parts with a **NON-PETROLEUM** based solvent.

Note: A cold boiler must be filled slowly and with return water from the mains no hotter than 140 Deg F. This is to ensure that the porcelain insulators and glass tubes are not heated too quickly. If the boiler is still hot, the feed water temperature should not be lower than the boiler temperature. Also, the boiler should not be heated/cooled quicker than 3-5 F per minute to protect the porcelain insulators from damage.

Lower Electrode Assembly

1. Electrode Housing
2. Copper Gasket (Triangular)
3. Electrode Bracket
4. Copper Gasket (Round)
5. Bracket Adapter*
6. Electrode Rod*
7. Graphite Gasket
8. Sponge Gasket 2-1/2" x 1-3/4"
9. Lower Centering Ring
10. Sponge Gasket 2-1/2" x 1-3/4"
11. Sponge Gasket 2-1/2" x 1-3/4"
12. Quartz Tube
13. Sponge Gasket 2-1/2" x 1-3/4"
14. Porcelain Insulator
15. Graphite Gasket
16. Drip Shield**

*Tighten electrode rod to bracket adapter to approx. 100 ft-lb.

Do not use any lubrication. High temperatures will evaporate lubricants and cause electrical shorts.

**Place drip shield loosely over completed electrode assembly and proceed to electrode installation.

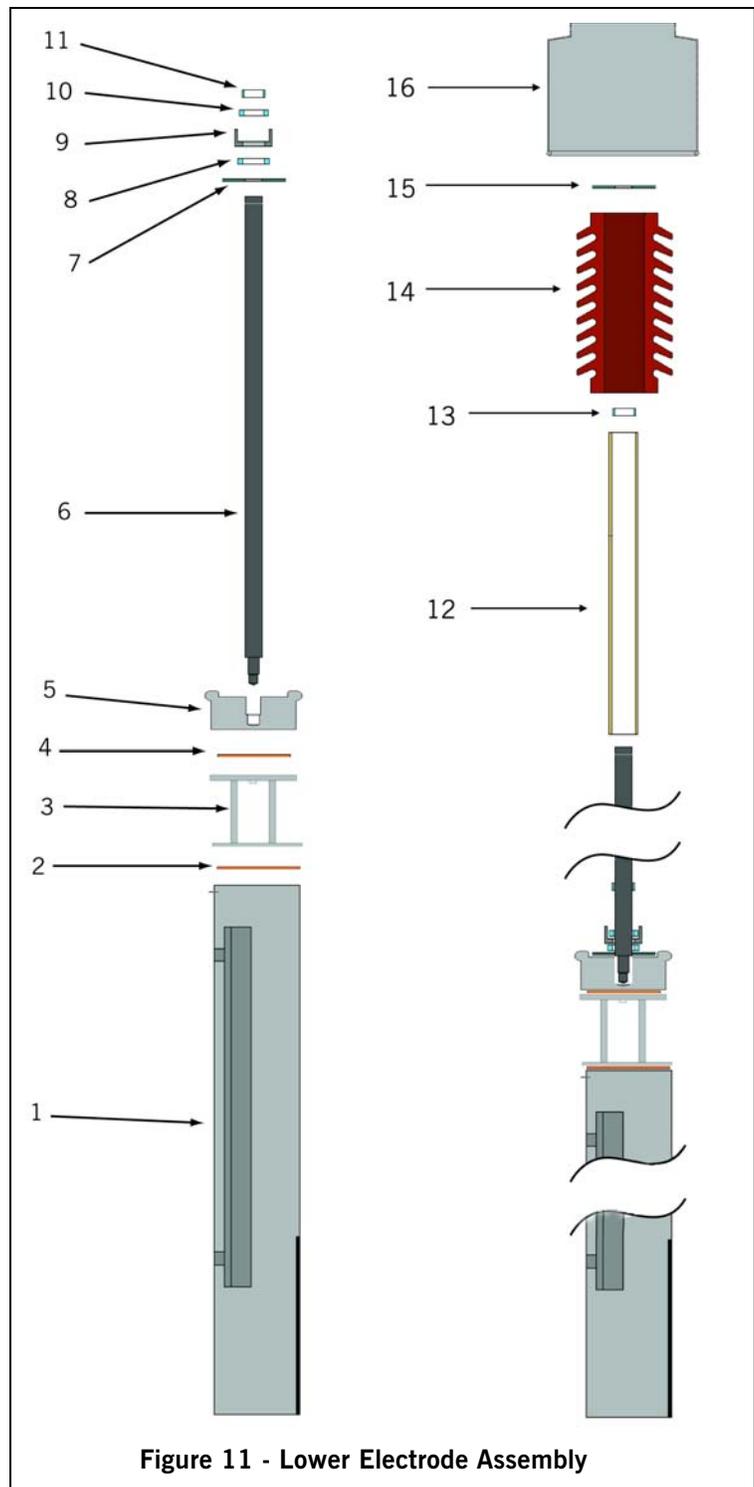
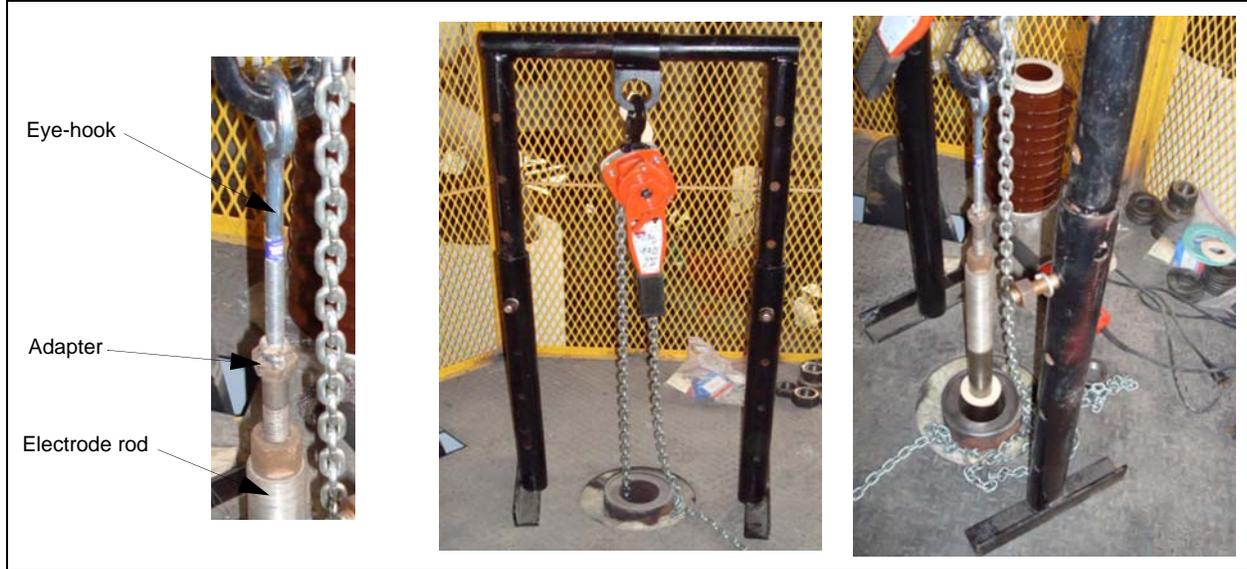


Figure 11 - Lower Electrode Assembly

Electrode Installation

- Install lifting eye-hook onto electrode shaft.
- Hoist the completed lower electrode assembly up through the boiler 's electrode fitting. Hoisting procedure will require careful handling of electrode by workers inside the boiler.



- Once the electrode is seated against the electrode bushing, use a bottle jack to support the assembly.



- Disengage the winch and begin upper electrode assembly (see Figure 12).
- Temporarily hand-tighten retaining nut and proceed to electrode positioning.

Upper Electrode Assembly

1. Graphite Gasket
2. Porcelain Insulator
3. Sponge Gasket 2-1/2" x 1-3/4"
4. Graphite Gasket
5. Upper Centering Ring
6. Spring Washers (see Figure 13 on pg. 38)
7. Spacer
8. Bearing
9. Retaining Nut

Caution

Check for required space between quartz and top of insulator.
Gaskets and centering ring must be snug but not over-tightened.

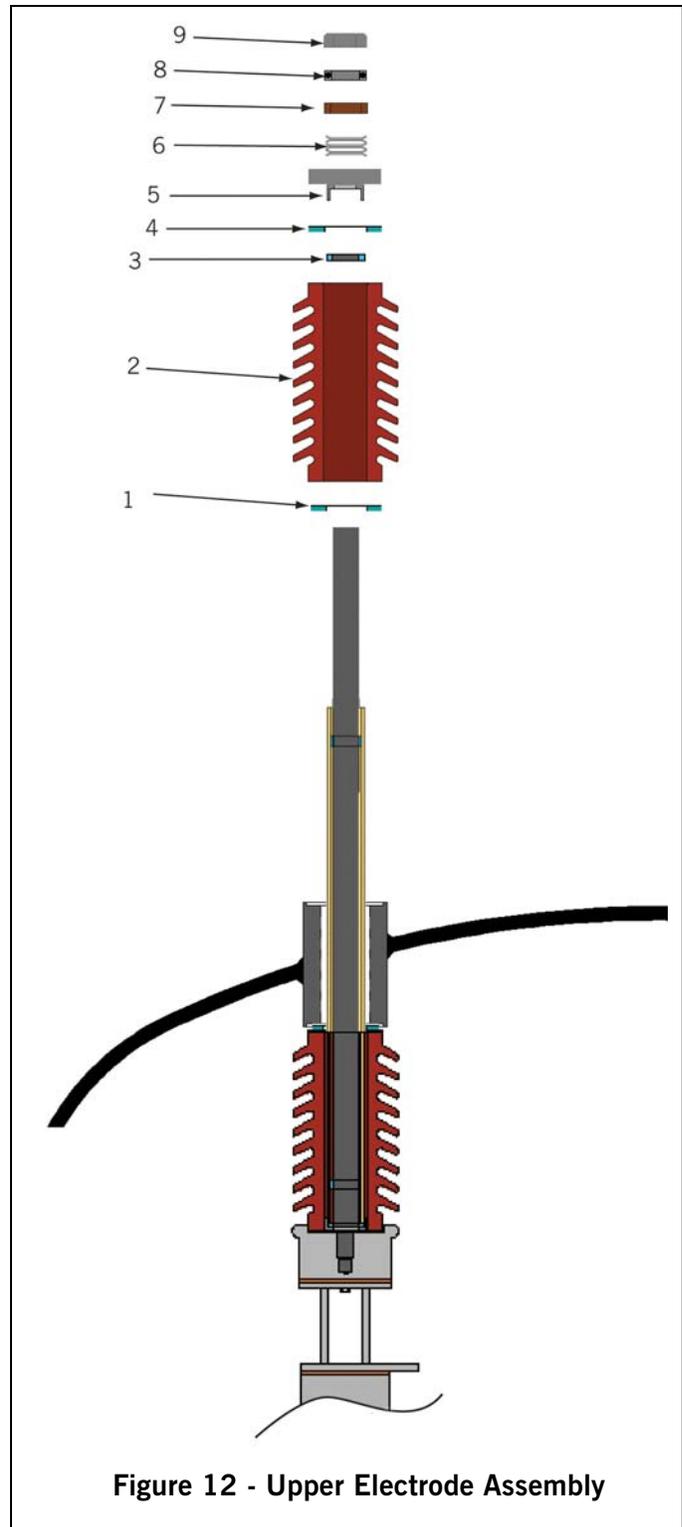


Figure 12 - Upper Electrode Assembly

Electrode positioning

- Space and center each of the electrode housings. The bottom plate of the electrode bracket is fitted with slots for front-back adjusting. Verify the electrode housing is squarely facing the nozzle plates.
- Tighten electrode retaining nut until washers are compressed to the appropriate specifications as shown below in Figure 13. While tightening, have an assistant inside the boiler verify that the electrode boxes do not move. If boxes turn, check rod threads for damage or nut binding. DO NOT forcefully restrain boxes during tightening. Refer to Figure 13 below for more details.



QTY	FREE HEIGHT COLD	COMPRESSED HEIGHT COLD	STACK DEFLECTION*	BOILER OPERATING PRESSURE (PSIG)	DEGREE TURN	# TURNS
10	3.77"	3.25" to 3.24"	0.522" to 0.532"	100 - 350	939 ° to 958 °	2.61 to 2.66
10	3.77"	3.24" to 3.23"	0.532" to 0.545"	350 - 500	958 ° to 981 °	2.66 to 2.73

* Stack deflection dimension is from hand-tight

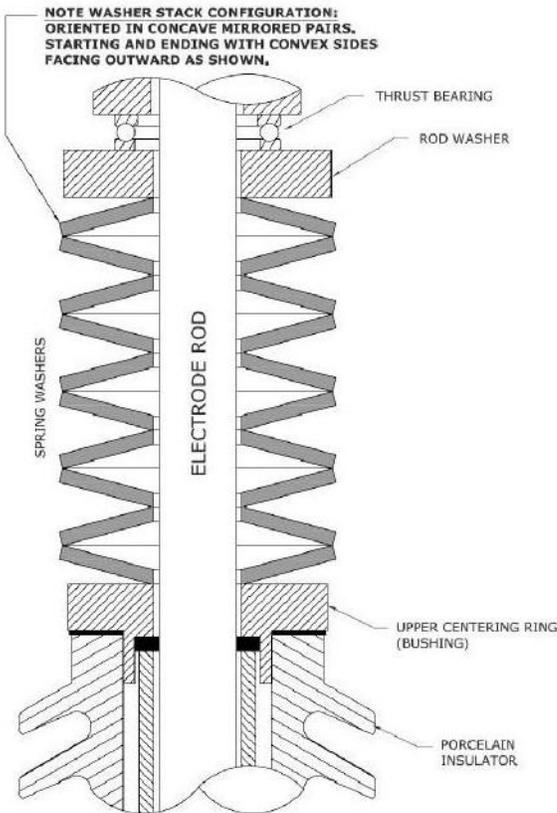
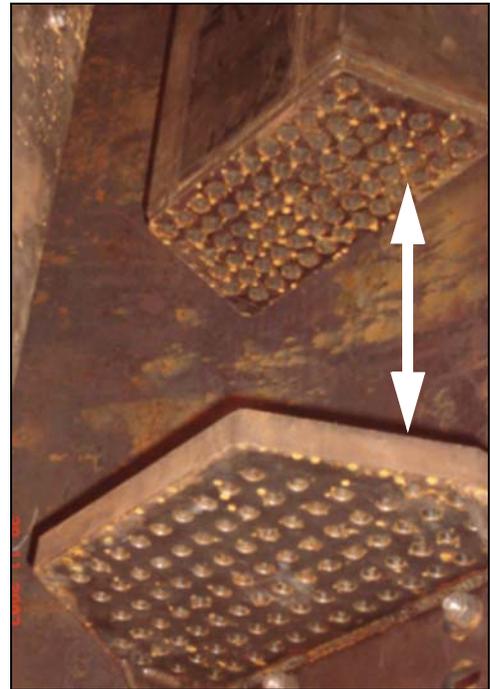


Figure 13 - Spring Washer Loading



Electrode positioning (continued)

- Measure and adjust distance between bottom of electrode boxes and counter electrodes.



- Measure and adjust the distance from each electrode box to the center water column nozzle plates. Each electrode box should be aligned perfectly parallel to the center column to ensure the nozzle openings align precisely with the target plates.



- After positioning electrodes, attach the drip shield to electrode bushing.



9.6-Packing of gland housing assembly for control rod

The control rod gland housing packing must be replaced/repared once a steam leak is realized. The packing can be tightened without completely replacing all material every time. Refer to the steps below for details to ensure the gland housing is properly packed and to minimize the risk associated with improper packing techniques. Figure 14 also shows a detailed drawing of the gland housing assembly to further assist with this procedure. The gland housing for the control rod should be checked for leaks within 2-4 weeks of initial operation after the gland housing assembly has been packed.

1. Begin by tightening the Gland Sleeve nuts (Item 6) to easily resolve the leaking steam issue. Proceed to Step 2-4 below if the tightening of this nut does not remedy the steam leak. CAUTION: Alleviate all pressure in boiler before attempting to remove any component of gland housing assembly.

2. To access the packing material, remove the Gland Sleeve (Item 1). This is accomplished by removing the Gland Sleeve nuts (Item 6) and stud bolts (Item 4).

NOTE: Two different types of packing material are used in this process. Please notice that the firmer round Carbon Braid packing (Item 7) is used on the outside (top & bottom) of the packing assembly. The 5 to 7 inner layers are comprised of softer square Graphite packing (Item 8) to ensure a better air-tight seal.

3. Remove the top-most round Carbon Braid packing (Item 7). Add sufficient layers of the square Graphite packing (Item 8), alternating the locations of the seam with each layer. Add a fresh layer of round Carbon Braid packing (Item 7) to top of packing assembly.

NOTE: If all packing material must be replaced, begin with a fresh bottom layer of round Carbon Braid packing (Item 7). Add 5 to 7 middle layers of square Graphite packing (Item 8). A top layer of round carbon Braid packing is needed to finish the packing "sandwich". See Figure 14 for reference. To ensure the best possible seal, cut ends of square Graphite packing (Item 8) to meet flush at 45 degree angles.

4. Replace the Gland Sleeve (Item 1) and stud bolts (Item 4). Tighten the Gland Sleeve nuts (Item 6) to pack the material. There are no certain torque specifications for this procedure as the compression of the packing is never constant. Be sure to leave a 1/2" to 3/4" gap between the gland sleeve (Item 1) and the gland housing (Item 3) to allow for future compression when the assembly is initially packed.

NOTE: Packing of gland housing assembly for control rod should be checked for leaks within 2-4 weeks of initial operation after the gland is packed. Tighten Gland Sleeve nuts (Item 6) as necessary.

ITEM	DESCRIPTION
1	GLAND SLEEVE
2	GLAND BUSHING, BRONZE
3	GLAND HOUSING
4	STUD BOLT
5	GASKET RING (GARLOCK)
6	NUT, HEX
7	PACKING, CARBON BRAID (ROUND)
8	PACKING, GRAPHITE (SQUARE)

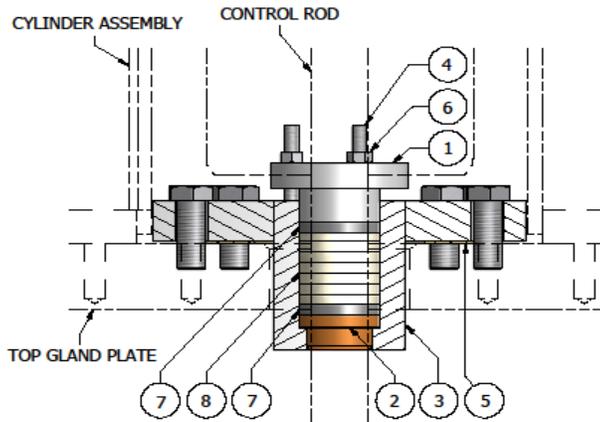


Figure 14 - Gland Housing

10 - Layup

At times it is desirable to shut the boiler down for an extended period ("Layup"). The preparation method used depends on the duration of layup and on how much time it is convenient to take in placing the boiler back into service.

For short-term shutdown (up to one or two months) the boiler may be left on standby with the standby heater keeping the boiler hot and under some pressure. This will keep all gaskets tight and will leave the boiler ready for use.

If the boiler is to be shut down and allowed to cool off, the water left in the boiler should be treated with hydrazine (100 ppm). The steam space should be filled with nitrogen to a pressure of 1 or 2 psi.



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