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A DEVELOPMENT OF

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BUC-EE'S TRAVEL CENTER

BENTON, ARKANSAS

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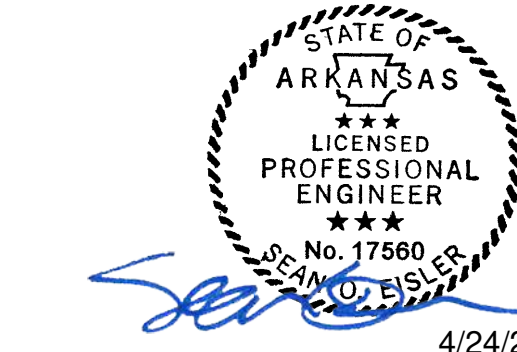
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MECHANICAL CONTROLS

LSL PROJECT NUMBER: 2024-107.000

BENTON, ARKANSAS

SEQUENCE OF OPERATIONS HOT WATER HEATING PLANT

This sequence of operations is organized into the following main categories: operating modes; control setpoint resets; safeties, overrides and interlocks; and component control loops. The operating modes describe the criteria that either enable or disable the various modes of operation. If a mode of operation is not listed within a component control loop section then that mode of operation has no direct influence on the operation of the component. The control setpoint reset section describes the logic and reference variables that will be used to reset control setpoints to a new value within its reset range. The safeties, overrides, and interlocks section outlines the hardwired interlocks that will be required to meet life safety requirements. Safeties and interlocks take precedence over all other control strategies outlined in this document. The control responses of each component for the various modes of operation are described in the component, control loop sections. Setpoints shall be adjustable (adj.) as noted.

The sequence of operations, the points list and control diagrams shall be used to provide a complete description of the control philosophy for the controlled/equipment. Individual setpoint values, reset ranges, and alarm action levels are listed in the points list. Components and control sensor locations are graphically depicted on the control diagram. The controls contractor shall be responsible for coordinating any necessary time delay setpoints to establish stable system operation.

GENERAL DESCRIPTION

The heating hot water plant described by this sequence of operations consists of condensing boilers with in-line circulator pumps, variable speed pumps to provide heating hot water to the facility.

Master Firing Controller BAS Interface:

The building automation system (BAS) shall provide a remote enable signal; remote setpoint adjustments; and visibility of the master controller at the operator's workstation as defined in the hot water plant points list. The communication protocol shall be coordinated with the provided manufacturer.

OPERATING MODES

HOT WATER PLANT DISABLED MODE:

The hot water plant shall be in disabled mode when:

The operator has manually disabled the plant at the operator's workstation or by a local disable switch.

Or- there is no call from the automatic or manual enabled modes as defined below.

HOT WATER PLANT ENABLED MODE:

The plant shall be in enabled mode when any of the following enable methods is employed and the conditions are satisfied. The automatic enable mode shall be the basis of design enable mode.

Automatic Enable Mode: The plant shall be enabled when there is a call for heating among active heating coil valves. BAS shall be capable of excluding valves from the active heating coil valve list.

The following heating coil valves shall be included in the automatic enable mode:

All heating coil valves shall be included in the analysis.

A call for heating is generated by the BAS when any one active heating coil valve is commanded at least 15% open for greater than 10 minutes;

Or- any one heating coil valve is at least 80% open for 10 minutes.

Or- When the outside air is less than 50 F subject to the boiler master controller outside air temperature sensor (BMFC-OAT).

Manual Enable Mode Option: The plant shall be manually enabled when the operator manually places the plant in enabled mode at the operator workstation or at the master firing controller furnished with the boiler(s).

BOILER ENABLED/DISABLED MODE:

A boiler shall be enabled and disabled via command from the boiler master firing controller (B-C-X).

BOILER MANUAL START MODE:

A boiler shall be in manual start mode when manually enabled through the equipment control panel.

BOILER FAILURE MODE:

A boiler shall be in failure mode when the equipment control panel reads any alarm condition.

AHU FREEZE PROTECTION MODE:

The boiler plant shall be in freeze protection mode upon a signal that any associated air handling unit (AHU) is in a freeze protection mode while the heating hot water plant is in disabled mode.

LOSS OF POWER RESTART DELAY MODE:

The plant shall be in loss of power mode upon restoration of power after an unexpected loss of power. The plant shall remain in this mode for the duration as defined by the plant start delay (PSD) setpoint. Once the plant start delay duration has elapsed, the plant shall return to its previous mode prior to loss of power.

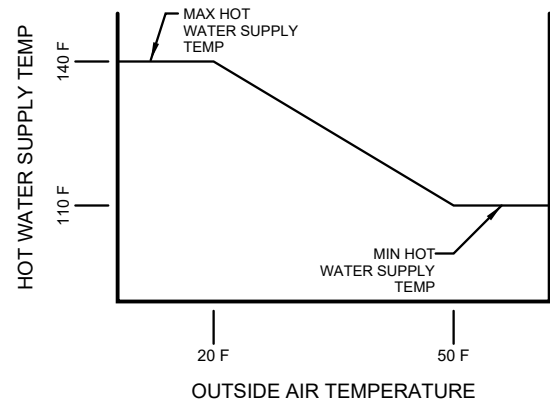
PUMP FAILURE MODE:

A pump shall be in failure mode when:

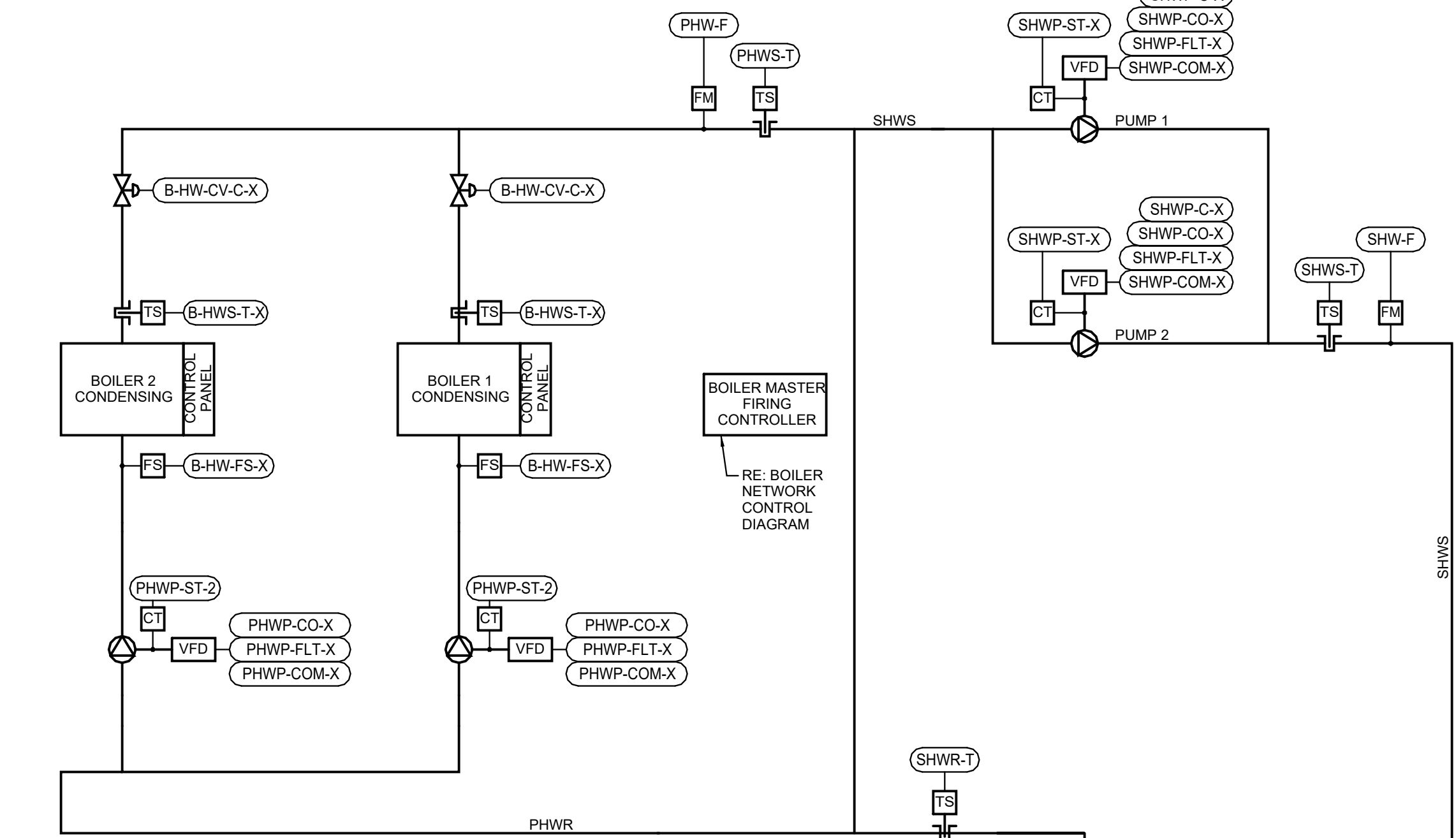
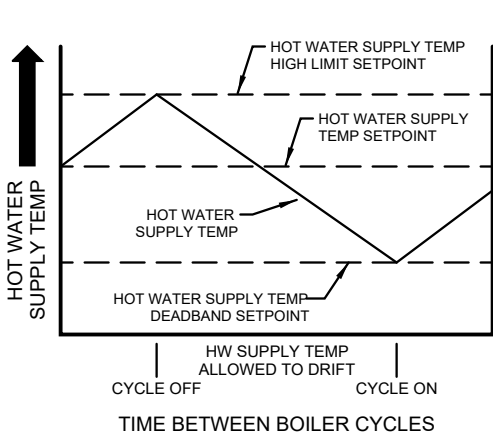
The pump is given a start signal;

And- The pump status indicates it is off.

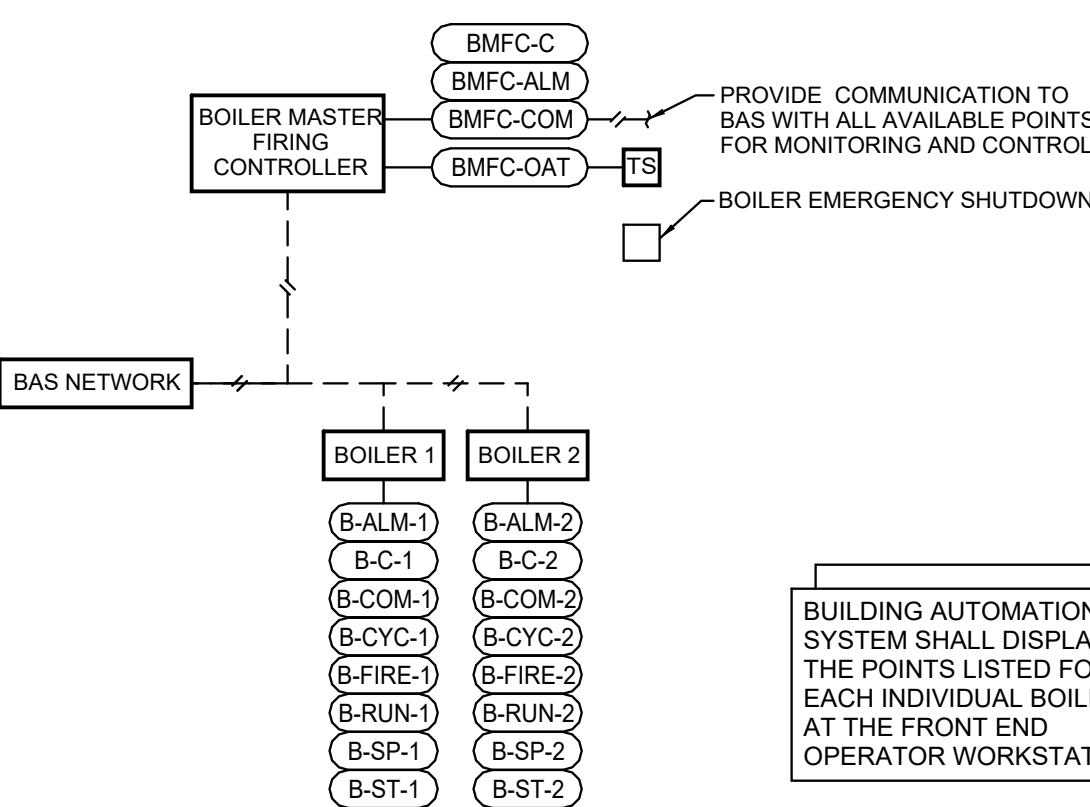
HEATING HOT WATER SUPPLY TEMPERATURE RESET BASED ON OUTSIDE AIR TEMP



HEATING HOT WATER SUPPLY TEMPERATURE DEADBAND



BOILER NETWORK CONTROL DIAGRAM



POINTS LIST - HEATING HOT WATER PLANT

POINT ID	DESCRIPTION	POINT TYPE	DEFAULT SETPOINT	SETPOINT RESET RANGE	FAIL POSITION	STATUS ALARM	ALARM RANGE	NOTES
GLOBAL VALUES								
B-EMSTP	HOT WATER PLANT EMERGENCY PUSHBUTTON	BI				X	ON ACTIVATION	C, E
FA-SO	FIRE ALARM SHUTDOWN AND STATUS	BV						B
OAT	OUTSIDE AIR DRY BULB TEMPERATURE	AV						B
PSD	PLANT LOSS OF POWER RESTART DELAY	AV		TBD				G, H
BOILER MASTER FIRING CONTROLLER								
BMFC-C	CONTROLLER COMMAND	BO						D
BMFC-COM	CONTROLLER COMMUNICATION	COM						F
BMFC-ALM	CONTROLLER ALARM	BI				X	COMMON ALARM	
BMFC-OAT	CONTROLLER OUTSIDE AIR DRY BULB TEMPERATURE	AV						D
BOILER CONTROL PANEL (TYPICAL ALL BOILERS)								
B-ALM-X	BOILER ALARM	BI				X	COMMON ALARM	K
B-C-X	BOILER COMMAND (START/STOP)	BO						
B-COM-X	BOILER COMMUNICATION	COM						F
B-CYC-X	BOILER BURNER CYCLES	AV						K
B-FIRE-X	BOILER PERCENT FIRING RATE	AV						K
B-RUN-X	BOILER OPERATING HOURS	AV						K
B-SP-X	BOILER HOT WATER SUPPLY TEMPERATURE SETPOINT	AV	140 F	110 - 140 F				K
B-ST-X	BOILER STATUS	BV						K
BOILER SENSORS AND VALVES								
B-HW-CV-C-X	BOILER HOT WATER ISOLATION VALVE COMMAND	BO			NO			A, J
B-HWS-T-X	BOILER HOT WATER SUPPLY TEMPERATURE	AI	140 F	110 - 140 F				K
B-HW-FS-X	BOILER FLOW SWITCH	BI						A
PRIMARY HOT WATER LOOP								
BHWS-T-DB	HOT WATER SUPPLY TEMPERATURE DEADBAND	AV	(PHWS-T) - 10 F					G
BHWS-T-HL	HOT WATER SUPPLY TEMPERATURE HIGH LIMIT	AV	(PHWS-T) + 10 F					G
PHWS-T	PRIMARY HOT WATER SUPPLY TEMPERATURE	AI	140 F	110 - 40 F				A, G
PHW-F	PRIMARY HOT WATER FLOW	AI						A
PRIMARY HOT WATER PUMP (TYPICAL ALL PUMPS)								
PHWP-CO-X	PRIMARY HOT WATER PUMP SPEED OUTPUT	AO	TBD	MIN - 60 Hz	X		PHWP-CO < MINIMUM	G, H
PHWP-COM-X	PRIMARY HOT WATER PUMP VFD COMMUNICATION	COM						F
PHWP-FLT-X	PRIMARY HOT WATER PUMP FAULT	BI				X	COMMON ALARM	
PHWP-ST-X	PRIMARY HOT WATER PUMP STATUS	BI				X	PHWP-ST <=> PHWP-C	
HOT WATER LOOP								
SHWR-T	SECONDARY HOT WATER RETURN TEMPERATURE	AI						A
SHWS-T	SECONDARY HOT WATER SUPPLY TEMPERATURE	AI						A
SHW-F	SECONDARY HOT WATER FLOW	AI						A
SHW-DP-X	SECONDARY HOT WATER DIFFERENTIAL PRESSURE	AI	TBD	TBD			HW-DP <+ 5 PSIG OF SPT	A, G, H
SECONDARY HOT WATER PUMP (TYPICAL ALL PUMPS)								
SHWP-C-X	SECONDARY HOT WATER PUMP COMMAND	BO						
SHWP-CO-X	SECONDARY HOT WATER PUMP SPEED OUTPUT	AO	TBD	MIN - 60 Hz	X		SHWP-CO < MINIMUM	G, H
SHWP-COM-X	SECONDARY HOT WATER PUMP VFD COMMUNICATION	COM						F
SHWP-FLT-X	SECONDARY HOT WATER PUMP FAULT	BI				X	COMMON ALARM	
SHWP-ST-X	SECONDARY HOT WATER PUMP STATUS	BI				X	SHWP-ST <=> SHWP-C	

ALL POINTS SHOWN SHALL BE PROVIDED BY BAS CONTRACTOR UNLESS NOTED OTHERWISE.

NOTES:

- BAS CONTRACTOR SHALL PROVIDE DEVICE.
- DISPLAY VALUE WITH CENTRAL PLANT GRAPHIC AT BAS FRONT END. REFERENCE GLOBAL BUILDING MONITORING SCHEDULE FOR CONTROL POINT.
- DIVISION 26 SHALL PROVIDE DEVICE. PROVIDE ONE EMERGENCY PUSH BUTTON AT EACH EXIT DOOR TO THE BOILER ROOM. REFERENCE PLANS FOR LOCATION.
- BOILER MANUFACTURER SHALL PROVIDE DEVICE.
- HARD-WIRE POINT DIRECTLY TO THE BOILER CONTROL PANEL.
- PROVIDE RS-232 OR RS-485 COMMUNICATION LINK.
- POINT SHALL BE ADJUSTABLE.
- DETERMINE SETPOINT IN FIELD.
- PROVIDE FAST ACTING VALVE. COORDINATE VALVE ACTUATING TIME PERIOD WITH BOILER MANUFACTURER TO MAINTAIN OPERATION DURING BOILER STAGING.
- OBTAIN POINT THROUGH THE BOILER CONTROL PANEL.

CONTROL SETPOINT RESETS

HOT WATER PUMP DIFFERENTIAL PRESSURE RESET:

The secondary hot water differential pressure setpoint (SHW-DP) shall be reset using valve command position within the range limits scheduled on the points list via firm and respond logic. The trim and respond function shall reset the setpoint incrementally downward to maintain one active control valve output signal greater than 90% open.

Trim and respond logic:

When pump is off, reset setpoint to the default value.

While pump is proven on:

If all control valves included in the analysis are less than 90% open (adj.), every 2 minutes (adj.) decrease setpoint by 0.5 psig (adj.). Repeat trim and respond logic until at least one (adj.) control valve is greater than 90% open.

If at least one control valve is greater than 95% open (adj.), every 2 minutes (adj.) increase setpoint by 0.5 psig.

When using both a trim and respond temperature reset and pressure reset and the temperature reset is programmed to be enabled first, the pressure reset sequence shall not be enabled until:

The secondary hot water supply temperature (SHWS-T) has reached its minimum reset value for 10 minutes (adj.).

And- All active control valves included in the reset analysis are less than 90% open.

While the pressure reset sequence is enabled, the hot water supply temperature setpoint shall be held constant at its minimum reset value. The reset sequence shall be disabled when:

The secondary hot water differential pressure setpoint (SHW-DP) has reached its minimum reset value for 10 minutes (adj.).

And- when any 3 (adj.) active heating coil control valves included in the reset analysis are greater than 90%.

HOT WATER PLANT TEMPERATURE RESET:

Reset Based on Outside Air Temperature: The secondary hot water supply temperature setpoint (SHWS-T) shall linearly reset based on the outside air temperature (BMFC-OAT) by the following schedule:

Reset Based on Trim and Respond Logic: The secondary hot water supply temperature (SHWS-T) shall be reset within the temperature range limits scheduled on the points list using trim and respond logic. The trim and respond function shall reset the setpoint incrementally downward to maintain one active control valve output signal greater than 90% open.

Trim and respond logic:

When pump is off, reset setpoint to the default value.

While pump is proven on:

If all control valves included in the analysis are less than 90% open (adj.), every 2 minutes (adj.) decrease setpoint by 0.5 F (adj.). Repeat trim and respond logic until at least one (adj.) control valve is greater than 90% open.

If at least one control valve is greater than 95% open (adj.), every 2 minutes (adj.) increase setpoint by 0.5 F.

When using both a pressure reset and temperature reset and the pressure reset is programmed to be enabled first, the temperature reset sequence shall not be enabled until:

The secondary hot water differential pressure setpoint (SHW-DP) has reached its minimum reset value for 10 minutes (adj.).

And- when any 3 (adj.) active heating coil control valves included in the reset analysis are greater than 90% open.

SAFETIES, OVERRIDES AND INTERLOCKS

BOILER FACTORY FURNISHED SAFETIES:

The boiler master firing controller shall monitor the factory provided safeties and interlocks and prevent firing of the boiler(s) until the internal safety conditions are met.

The factory boiler controller shall monitor the factory provided safeties and interlocks and prevent firing until the conditions are met.

Minimum water flow is "true" (B-HW-FS)

Flue damper is "open" (B-FD-FS)

Start purge cycle time is "completed"

Pilot gas valve and igniter is "open" and "on"

Proof of flame is "true"

The main gas valve is "open"

Coordinate field installation requirements for factory furnished and contractor installed devices (e.g. water flow switch and flue damper).

PRIMARY SAFETY SHUTDOWN PER ASME CSD-1:

The boiler shall shutdown and requires a manual supervised restart. Primary safety shutdown shall occur upon:

- Boiler flame failure - The boiler shall be allowed to cycle a second time before a primary safety shutdown is initiated. An alarm shall generate and the boiler shall enter Boiler Failure Mode.
- Emergency stop switch (B-EMSTP). The emergency stop switch shall interrupt power to the boilers and close the main gas valve.

HOT WATER PUMP(S) INTERLOCK:

Dedicated hot water pump(s) shall start when the associated boiler is enabled.

COMPONENT CONTROL LOOPS

BOILER MASTER FIRING CONTROLLER (BMFC):

The BMFC shall be furnished by the boiler manufacturer.

When in hot water plant disabled mode:

The boiler(s) are off subject to their own internal safeties and time delays.

When in hot water plant enabled mode:

The BMFC shall sequence the boiler(s) and boiler isolation valve(s) to maintain the primary heating hot water set point as measured by the hot water supply temperature sensor (B-HWS-T-X). The hot water temperature sensor shall be furnished by the BAS contractor.

The boilers shall be enabled and disabled according to a lead/lag schedule. The schedule shall be based on equal run time or cycle count, whichever comes first.

If the BMFC determines heat is required, it shall enable the lead boiler.

The BMFC shall monitor the water flow through the system using the communication protocol from the BAS. The controller shall stage on additional boilers based on maximum flow through a boiler and the supply header temperature sensor.

Sequential Staging: If the BMFC determines additional heat is required, it shall increase the firing rate of the lead boiler until it is at full fire. The BMFC shall enable lag boilers and modulate them up to full fire as required to maintain the hot water supply temperature setpoint.

If the BMFC determines less heat is required, it shall modulate the last enabled boiler down as required until it is at minimum fire.

If the primary hot water temperature continues to rise, the BMFC shall disable the lag boilers in reverse order, with the last boiler on to be the first boiler off.

When the last operating boiler stages off or a boiler stages off on high heat (B-HWS-T-HL), the boiler(s) shall not be allowed to stage back on until the hot water supply temperature is below the hot water supply temperature deadband (B-HWS-T-DB).

BOILER ISOLATION VALVE (B-HW-CV):

The boiler isolation valve shall be furnished by the BAS contractor, installed by the mechanical contractor, and shall be controlled by the boiler master firing controller.

When in boiler disabled mode:

The valve shall remain open for 5 minutes (adj.) after boiler shutdown for flow to dissipate residual heat. After the time period, the valve shall be closed.

When in boiler enabled mode:

The valve shall be open when the associated boiler is enabled. The valve shall be fast acting.

When in boiler manual start mode:

The valve shall operate as in boiler enabled mode.

When in boiler failure mode:

The valve associated with the boiler in alarm shall be closed.

When in hot water plant disabled mode:

The pump shall be off.

When in hot water plant enabled mode:

A pump that is on shall operate at a constant speed to maintain the scheduled water flow through the operating boilers as defined in the equipment schedule. Speed setpoint shall be determined by TAB during system startup.

The pumps shall be interlocked with their associated boiler.

When in pump failure mode:

If a pump fails to run, the associated boiler shall shut down, and the lag boiler shall start if not already running.

When in hot water plant disabled mode:

The pump shall be off.

When in hot water plant enabled mode:

The pumps shall energize subject to a lead/lag sequence. Sequence shall be based on equal run time.

A pump that is energized shall start on low speed and ramp up to maintain the hot water differential pressure setpoint as measured by the differential pressure sensor(s) (SHW-DP-X). Initial differential setpoint shall be determined during system startup. The most critical DP sensor shall govern pump speed. Multiple operating pumps shall ramp together to meet setpoint.

Optimized pump staging algorithm: Pumps shall energize on and off based on the optimum combination of primary pumps to minimize energy use. The test and balance contractor and controls contractor shall coordinate to field determine the optimized staging setpoints.

The test and balance contractor shall perform the following:

- Ramp one pump from minimum speed to design speed and record the total amp draw from the pump at every 3 Hz interval.
- Start another pump and repeat step 1 for the pumps operating simultaneously.
- Repeat step 2 until the amp draw for all scheduled pumps operating simultaneously has been recorded.

The pump staging setpoints shall be determined from the rpm speed at which operating more pumps at the same flow rate draws less amperage than the current quantity of operating pumps.

When staging on a lag pump:

- Ramp the operating pumps down to minimum speed.
- Turn the lag pump on.
- Ramp the operating pumps together to meet setpoint.

When staging off a lag pump:

- Ramp the operating pumps down to minimum speed.
- Turn the lag pump off.
- Ramp the remaining operating pumps together to meet setpoint.

When in pump failure mode:

The next lag pump shall be energized and operate as in hot water plant enabled mode.