CHAPTER 3
CONTROLLER: MODEL 90 OR 90N

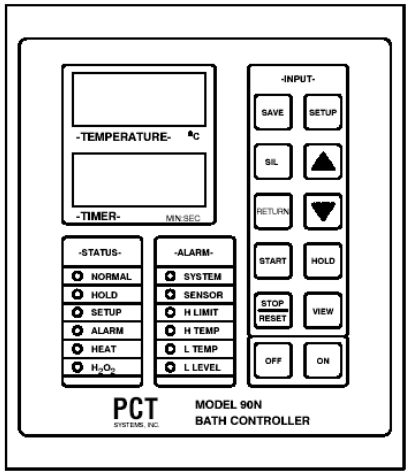
Purpose

This chapter discusses the:

- Product Overview of the controller
- 5 Primary Status Modes
- Alarms
- Input Keys
- Operation
- Tuning Discussion
- Backdoor Code
- System Specifications

Product Overview

Figure 3-1: Example of Typical Controller Face Plate



Two Setpoint Controller

The controller is a 2-setpoint controller (PID and ON/OFF).

- **SETPOINT I (PS)** is the bath process temperature.
- **SETPOINT II (HS SETTING)** drives a NORMALLY-CLOSED solenoid, which adds deionized water to the bath for makeup in Nitride Etch and Phosphoric Acid applications.

REMINDER:

The Setpoint II should be determined by your engineering staff according to your specifications and procedures.

IMPORTANT:

PCT Systems has temporarily set the Setpoint II (HS setting) temperature at 200°C to avoid any problems during start-up.

ALSO, **AT NO TIME** should the Setpoint II output to be ON continuously.

This situation may create a hazardous condition by adding more water than is required. Setpoint II is normally set 1°–2°C above Setpoint I.

PLEASE NOTE: PCT Systems is not recommending a setpoint, but rather, is reflecting an accepted industry procedure.

Technical Overview

The controller is a microprocessor-based controller/timer.

- It monitors temperature utilizing a Type-J thermocouple sensor and controls the bath temperature with a standard 3-mode (PID) control scheme with Anti-Reset Windup.
- Numerous status and alarm functions are incorporated to monitor various system parameters.
- A down-count/up-count programmable timer, with cumulative over-timer and pre-warn, is integrated into the system.
- A pilot-duty, photo-isolated, triac output is used to drive a remote heater power relay.
- An **OPTIONAL** power pack provides the on-board load carrying solid state switching.
- An **OPTIONAL** auxiliary relay can be utilized for either timer or DI output.
- An independent high limit circuit is provided.
    - It is powered by an isolation transformer that draws power from the primary side of the master relay. The sensor is a Type-J thermocouple. This circuit shuts OFF the internal master relay should an over-temperature condition occur.

- To indicate system and display status, as well as annunciate various alarms, 12 discrete LEDs are utilized.
- A 12-key membrane switch, incorporated in the face panel, allows for user setup and adjustment of the system, plus full timer control.
- To view both the process temperature and the timer simultaneously, 2 numeric displays are utilized.
  - Each of the displays has multiple diagnostic and setup functions that may be activated by the keyboard or by the microprocessor during various setup and alarm conditions.
- The microprocessor section consists of 2 circuit boards: one for display and the other for control.
  - The **CONTROL BOARD** contains 2 transformers and provides the isolated DC supplies (+5 volts and +12 volts) necessary to run the system. It also contains an instrumentation amplifier, A/D converter, EEPROM memory, and the microprocessors.
  - The **DISPLAY BOARD** contains all of the 7 segment and LED displays, as well as the audio transducer.

5 Primary Status Modes

The 5 primary status modes, indicated by LEDs on the face plate, are the:

- Normal Mode
- Hold Mode
- Alarm Mode
- Heat Mode
- Setup Mode

Normal Mode

This mode is the *normal condition* for the system.

It indicates that the system is operating within the defined parameters.

Hold Mode

This mode is a *standby condition* for the unit.

It allows all normal monitoring and timing functions while disabling the heater.

TO EXIT THIS MODE, either:

- Press the RESET key OR
- Depress the HOLD key a second time.

NOTE:
For safety reasons, the unit always starts up in the HOLD mode and is in this mode after a power failure.

When in the HOLD mode, the display reads "Hold".

Alarm Mode

The various alarm conditions are activated by many sources and annunciated by both the displays and an audio tone.

The mode indicator shows that an alarm has occurred and the system is still performing under the special conditions required by that alarm.

THE ONLY WAY TO EXIT THIS MODE is to clear the condition causing the alarm.

Heat Mode

This LED is illuminated whenever the heater is ON.

NOTE:
When the unit is near the setpoint, the LED continuously cycles ON and OFF.

Setup Mode

When in this mode, the SETUP key causes the controller to step through the display of parameters, shown, in order, in the following table:

Table 3-1: Table of Display Codes (in order) & Setting Ranges

Code	Description	Setting Range
CS	Clock Setpoint	0:00 to 99:59 (Minutes:Seconds)
PA	Pre-Alarm Offset	0:00 to 0:59 Seconds
PS	Process Setpoint	0.0–199.9°C
HS	DI Setpoint (optional)	0.0–199.9°C
HI	High Alarm Setpoint	0.0–199.9°C
LO	Low Alarm Setpoint	0.0–199.9°C
AC	Access Code	0–9999
CR	Cycle Rate	0–19 Seconds
Pb	Proportional Band	0.0–19.9°C
rE	Reset	0.0–19.9 Minutes
rA	Rate	0.0–19.9 Minutes
CA	Calibration	±9.9°C
CD	Clock Direction	UP/DN (Up or Down)
RL	Relay Logic	0=Timer During 1=Timer After 2=DI

UP/DOWN KEY

While in the SETUP mode, depressing either the UP or DOWN key causes the display to advance or retard, respectively.

Depressing either the UP or DOWN key once and releasing it allows the accurate setting of the least significant digit.

Holding down either the UP or DOWN key activates the automatic, rapid incrementing or decrementing of the display.

TO EXIT THIS MODE, press the RESET key.

RATE & RESET VARIABLES

This system may operate in either a 1-, 2- or 3-mode configuration.

SETTING THE RATE OR RESET VARIABLES TO 0.0 eliminates the respective function.

> **REMINDER:**
> The RATE and RESET settings adjust the sampling period directly in tenths of minutes. Thus, smaller numbers create more rapid sampling.

CALIBRATION ADJUSTMENT

The ***CA*** (***Calibration Adjustment***) allows the elimination of various sensor and system errors.

- Thermocouple sensors are manufactured within a specific tolerance.
- The tolerance may lead to a difference between the actual bath temperature and the temperature displayed.
- This error, coupled with the differential error caused by sheathing the sensor in materials, such as Teflon, may cause a difference in the actual bath temperature and display temperature.
- This difference is simply corrected by monitoring the bath temperature and utilizing the offset—to add or subtract the appropriate number of degrees—to bring the displayed temperature into compliance with the actual bath temperature.

SAVE KEY

While in the PROGRAM mode, depressing the SAVE key causes the setup parameters to be written into the EEPROM memory.

The save routine takes about 2 seconds to complete and is indicated by a series of dashes through the displays.

- This is a permanent (10-year minimum life) memory that does not require battery backup.
- This feature provides the OEM with the ability to program initial conditions prior to shipment, then, allows the user to modify these conditions and permanently save the new parameters.
- All this can be done from the keyboard.

Alarms

Visual Alarms

There are 6 visual alarms LEDS:

- System Alarm
- Sensor Alarm
- High Limit (H Limit) Alarm
- High Temperature (H Temp) Alarm
- Low Temperature (L Temp) Alarm
- Liquid Level (L Level) Alarm

Essentially, these alarms are visual annunciators of the system functions.

System Alarm

This alarm is a "catch-all" indicator for the miscellaneous diagnostics.

The malfunction of the EEPROM save routine is a good example. This alarm simply indicates to the operator that something has gone wrong, and the operator should either repeat the command or reset the unit.

Sensor Alarm

This alarm indicates a defective "sensor". The sensor is either OPEN or NOT CONNECTED.

- Special circuitry monitors the sensors for an OPEN circuit.
- The processor continually monitors the input and, if it detects an OPEN sensor, shuts OFF the heater output and activates the SENSOR alarm. When this action occurs, the process display alternately flashes the temperature and the code "***OP***", for open sensor.

High Limit (H Limit) Alarm

Powered by the high-limit power supply, the LED remains ON—even after the master relay has de-energized and shuts off the controller. This alarm alerts the operator that the system has shut down and why.

The LED is wired directly to the high limit circuit and lights whenever the high limit circuit turns the master relay OFF.

High Temperature (H Temp) Alarm

This alarm activates when the process temperature exceeds the high alarm setpoint.

When this condition occurs, the display alternately displays the process temperature and the code, "***HI***".

Low Temperature (L Temp) Alarm

This alarm acts in the same manner as the high temperature alarm, except it compares the process temperature to the low alarm setpoint.

After the system initially comes out of the warm-up mode, this alarm activates when the process temperature drops below the setpoint. In this case, the code, "***LO***" and the process temperature flash alternately on the display.

Liquid Level (L Level) Alarm

This alarm monitors an **OPTIONAL** Remote Liquid Level Sensing Circuit and activates when a low liquid level is detected. The code, "***LL***" and the process temperature flash alternately on the display.

Audio Alarm

All of the alarms previously described, activate an Audio Tone, the alarm status LED, and the Individual Alarm Annunciator.

The Tone and the LEDs alternate ON and OFF to draw attention to the alarm.

REMINDER:

As described in the "Visual Alarms" section, many of the alarms have additional visual displays to further define or draw attention to them.

Input Keys

The 12 keys available on the controller are the:

- View Key
- Setup Key
- Up Key
- Down Key
- Silence the Alarm (SIL) Key
- Return Key
- Save Key
- Hold Key
- Start Key
- Stop/Reset Key
- On Key
- Off Key

VIEW Key

When **NOT** in the SETUP mode, use this key to view the process setpoint and programmed process time.

This key is a momentary key that will change displays to show the corresponding setpoints, as along as it is depressed.

SETUP Key

Use this key to put the system into the SETUP mode. Once the system is in this mode, use this key to advance through the parameters.

TO PLACE THE UNIT IN SETUP MODE, press the SETUP key one time.

NOTE:
If access code protection is selected, an additional step is required.

See the "Access Code" section for more information.

TO SCROLL THROUGH THE SETUP PARAMETERS, enter the SETUP mode (by pressing the SETUP key), then press the SETUP key again.

TO EXIT THE SETUP MODE, depress the RETURN key.

UP Key

TO ADVANCE THE DISPLAY, enter the SETUP mode (by pressing the SETUP key once), then press the UP key.

- Depressing the UP key one time and releasing it allows the accurate setting of the least significant digit.
- Holding the UP key down activates the automatic, rapid incrementing of the display.

DOWN Key

TO CAUSE THE DISPLAY TO DECREASE, enter the SETUP mode (by pressing the SETUP key once), then press the DOWN key.

- Depressing the DOWN key one time and releasing it allows the accurate setting of the least significant digit.
- Holding the DOWN key down activates the automatic, rapid decrementing of the display.

Silence the Alarm (SIL) Key

This key allows for the elimination of the audio portion of the alarm as well as the portion of the alarm display that affects the process display.

This action allows the unit to be returned to a functional condition where the setpoints can be examined and reset without the interference of the special alpha displays.

NOTE:
However, the alarm status and annunciator LEDs will continue to flash to indicate the alarm. Where applicable, the output to the heater is turned OFF to protect the equipment from any potential damage.

RETURN Key

WHEN THE SYSTEM IS IN THE SETUP MODE, press the RETURN key to return the system the standard operating mode.

IF THE SYSTEM IS IN THE HOLD MODE, press the RETURN key to exit the HEATER HOLD mode.

SAVE Key

When in the SETUP mode, press the SAVE key to permanently save the system parameters.

> **IMPORTANT:**
> The SAVE key is only active in the SETUP mode.

HOLD Key

Pressing the HOLD key puts the unit into the HOLD mode.

This mode disables the heater output.

When in the HOLD mode, the timer display reads "HOLD".

TO EXIT THIS MODE, either depress the RESET key or depress the HOLD key a second time.

> **NOTE:**
> For safety reasons, the unit always starts up in the HOLD mode or enters the HOLD mode after a power failure.

START Key

Pressing the START key activates the timer.

Pressing the START key also starts the system if it has been reset, or it will continue if the timer has been placed in the HALT mode.

For more information about the HALT mode, see the "Stop/Reset Key" *section.*

STOP/RESET Key

This multifunctional key's purpose varies with the current system mode.

IN THE RUN MODE

If the timer is running, pressing the STOP/RESET key stops the count and places the system in the HALT mode.

IN THE HALT MODE

If the timer is in the HALT mode, pressing the STOP/RESET key resets the timer in preparation for the next run.

ON Key

Pressing the ON key turns ON the main power to the controller by ***activating*** the internal electronic latch and master relay.

OFF Key

Pressing the OFF key turns OFF the main power to the controller by ***deactivating*** the internal electronic latch and master relay.

Operation

Timer

The timer may be configured *either* to count up or to count down.

- **IN THE SETUP MODE,** the timer is programmed to a specific time, a specific pre-alarm offset, and a count direction.
- **DEPENDING ON THE MODE SELECTED,** the UP/DOWN count time can be pre-set and will count down from the pre-set time or count up to the pre-set time. In both cases, it has the additional feature of accumulating overcount.
- **IN THE COUNT DOWN MODE,** once the timer counts down to zero (0), it begins counting up to record the time that has elapsed passed the pre-set time.
- **IN THE UP COUNT MODE,** once the timer reaches the pre-set value, it returns to zero (0) and counts up again to record the time that has elapsed passed the pre-set time.
- **IN BOTH MODES, WHEN THE DISPLAY IS IN OVERCOUNT**, the display flashes to indicate this condition.

The VIEW key may be used to examine the pre-set time.

- This value and the initial pre-set time are stored in the EEPROM memory, thus, they automatically are ready when the system is initially powered up.

Press the START key to start the timer.

- This condition is valid if the unit is in the NORMAL mode and the timer has been reset.

In the RUN (normal) mode, press the STOP/RESET key to stop the timer.

- When the timer is in the RUN mode, pressing the STOP/RESET key halts the system's operations and freezes the display on the current timer value. If the count is "over", the display will flash.
- A second depression of the STOP/RESET key causes the timer to reset. This action places the pre-set value in the timer display, stops the display flashing, and cancels any timer audio tones.

If the START key is pressed when the timer is in the HALT mode, the timer will continue from its current count.

The ***Pre-Warn Tone*** has a 50/50 duty cycle and a 1/2-second period.

- After the pre-set time has elapsed, the pre-warn tone turns into a continuous tone.
- The timer must be stopped to enter the PROGRAM mode.
- In the SETUP mode, the pre-set time and pre-warn tone are entered.

  For more information, please see the "Setup Key" *section of this chapter.*

High Limit Circuity

The unit contains special ***High Limit Circuitry***.

This circuitry consists of a redundant ***Single-Setpoint Temperature Monitor*** built into the same package.

This monitor is powered by a separate ***Isolation Transformer*** and utilizes the totally independent ***High Limit Thermocouple***.

The monitor's purpose it to monitor the bath for excessive temperature and, should such a condition occur, physically turn OFF the unit.

NOTE:

This system is different than the *high alarm setpoint*, which is a **SOFTWARE** function under microprocessor control.

The high limit circuitry is a redundant **HARDWARE** function capable of turning OFF the controller, independent of the basic control system.

The high limit thermocouple is processed through an ***Instrumentation Amplifier*** that also provides the reference and cold junction compensation. This signal, which is a measure of the thermocouple temperature, is compared to a pre-calibrated mechanical setpoint.

IF THE TEMPERATURE AT THE THERMOCOUPLE EXCEEDS THE RESET VALUE, the circuit turns OFF the internal load carrying master relay. Its also LIGHTS the high limit LED alarm light.

- If the unit is ON when this condition occurs, the unit will shut OFF.
- If the unit is OFF, it cannot be turned ON until this high limit condition is cleared.

NOTE:
Again, the high limit circuit is powered by its own transformer and, thus, remains ON at all times—even when the power switch is OFF.

The heater and microprocessor sections are electrically connected to the master relay output and, thus, are disabled by this alarm.

Access Code

In some cases, it may be desirable to ***restrict access to the SETUP mode***. To do this, an access code system is incorporated.

- **IF THE ACCESS CODE IS SET TO 0000,** the function is eliminated and the system operates as previously described.

The code is any number from 1–9999, and is determined and programmed into the system by the customer's authorized personnel.

- After this code is entered into the EEPROM, any attempt to enter the SETUP mode will cause an "***AC***" to appear in the display. The UP and DOWN keys are then used to enter the access code. After the proper code has been entered, the operator simply depresses the SETUP key to access the parameters.

Rate/Reset

The controller may operate in either a 1-, 2-, or 3-mode configuration.

SETTING THE RATE OR RESET VARIABLES TO 0.0 eliminates the respective function.

NOTE:
The RATE and RESET settings adjust the sampling period directly in tenths of minutes.

Smaller numbers create a more rapid sampling.

For more information about sampling, please see the "Tuning Discussion" *section of this chapter.*

Timer Relay

When the optional auxiliary relay is provided, the logic for the relay is selected by the "***RL***" parameter in the setup stack.

The relay responds as follows:

RL=0 (DURING)

This configures the auxiliary relay as a timer relay.

It is active for the period that the timer is active.

It activates when the timer is started and deactivates when the timer has completed its count.

RL=1 (DONE)

This configures the auxiliary relay as a timer relay.

It activates at the completion of the timer cycle.

It remains active until the timer is reset.

DI Relay

When the auxiliary relay is provided, the logic for the relay is selected by the "***RL***" parameter in the setup stack.

If **RL=2**, then the relay is designated as an DI relay. This relay is active when the process temperature is above the HS setting.

Snap Switch

The unit has provisions for the connections of a normally closed snap switch as a redundant high temperature safety. This connection allows the snap switch to be placed in series with the internal master relay coil.

When the snap switch is OPEN, the unit is shut OFF.

Tuning Discussion

Overview

The control scheme used in this controller is a standard PID system with Anti-Reset Windup.

This section briefly reviews PID control *as it relates to this system*.

> **NOTE:**
> This discussion specifically relates to this device and may be somewhat different for other systems.

Proportional Mode

The terms ***PID*** and ***3-Mode*** are interchangeable.

The first mode of control, ***P*** (***Proportional***), refers to the basic control scheme.

The concept is that the controller determines the percentage of heat required by the system, and adjusts the average power input to the heater to balance the system.

The power to the heater is either fully ON or fully OFF.

The proportional amount is a ratio of the amount of time ON to the amount of time OFF. Thus, proportional control, in this application, is more correctly termed ***Time Proportioning***.

Cycle Rate

The ***Cycle Rate*** (***CR***) setting is used to determine the rate at which the heater power is turned ON and OFF.

The proportioning of the output power is accomplished by varying the percentage of time that the unit is ON during the period.

For example, if CR=10, the unit will cycle ON and OFF once every 10 seconds.

If the process has determined that the system requires only half of the temperature, the output will be ON for 5 seconds and OFF for 5 seconds in a continuous cycle.

As the heat requirement varies, this percentage increases to slightly longer periods ON, such as 5.1 seconds ON, and 4.9 seconds OFF.

The opposite is also true for decreasing heat load requirements. Thus, when the system is at or near the setpoint, the HEAT LED in the status box flashes continuously, indicating the time proportioning of the heater.

To compute the required percentage of ON-time, the system utilizes the ***Proportional Band*** (***PB***) as set in the Programming mode. It is over this band that the output will vary from 0–100%.

If, for example, the setpoint is at 100°C and the Proportional Band is set at 10°C, the controller time proportions the output from 100% to 0% when the process temperature varies from 90°–100°C. When the process temperature is at 90°C and less, the output is fully ON. For temperatures from 90^0–100^0C, the output proportions from 100% down to 0%. For temperatures above 100°C, the output is fully OFF.

NOTE:

At this point, it is important to note that we are discussing systems in which the RATE and RESET functions are not used. RATE and RESET will cause a shifting in the Proportional Band and vary the percentages just discussed. However, RATE and RESET do not affect the basic theory, only the position of the Proportional Band at any moment in time.

Proportional Band and Cycle Rate Relationship

Now, we will tie the Proportional Band and Cycle Rate together using the previous example.

We have a cycle rate of 10 seconds with a Proportional Band of 10°C and a setpoint of 100°C.

When the process temperature is 96°C, we see that it is 40% into the Proportional Band.

Based on this position, we require 40% heater output, with the 10 second Cycle Rate. This means that the heater is ON for 4 seconds and OFF for 6 seconds.

Obviously, a proportional control requires a certain degree of error to have the heat ON. Therefore, in the example just given, if we find that only 10% of the heat is required to maintain the desired temperature, then the unit will cycle 1 second ON and 9 seconds OFF, and the temperature will stabilize at 99°C. *This is not the desired 100°C!* The difference between the two points is termed, ***Droop***.

- ***Droop*** is the difference between the Setpoint and the Control Point in a proportional system.

Integral Mode or Automatic Reset Mode

To remove this Droop, we need the second mode, the ***I*** (***Integral***) mode or, more commonly termed, ***Automatic Reset Mode***.

The program calculates the difference between the current process temperature and the desired setpoint, then mathematically corrects the system to compensate for this error.

How often this correction occurs is based on the parameter programmed in the ***RE*** (***Reset Adjustment***) parameter.

Anti-Reset Windup is a special feature incorporated in the software that locks out the Reset function when the system is outside of the Proportional Band. Obviously, if the system was automatically adjusting the Droop before the system was nearing stability, large errors would occur. Anti-Reset Windup is used to eliminate such potential errors.

Derivative Mode

The third mode in the PID scheme is the ***D*** (***Derivative***) mode or, more commonly referred to as, ***Rate***.

When a system has large step changes in heat requirements, it may require this third mode to compensate for such changes.

Its primary function is to eliminate "overshoots" as the temperature is stabilizing. This mode controls the rate of change of the temperature when large temperature fluctuations occur.

On systems where overshoot is not a problem, the Rate function may be eliminated.

In general, bath control requires reset on all occasions. Rate may not be required and should be set to zero (0), unless overshooting occurs.

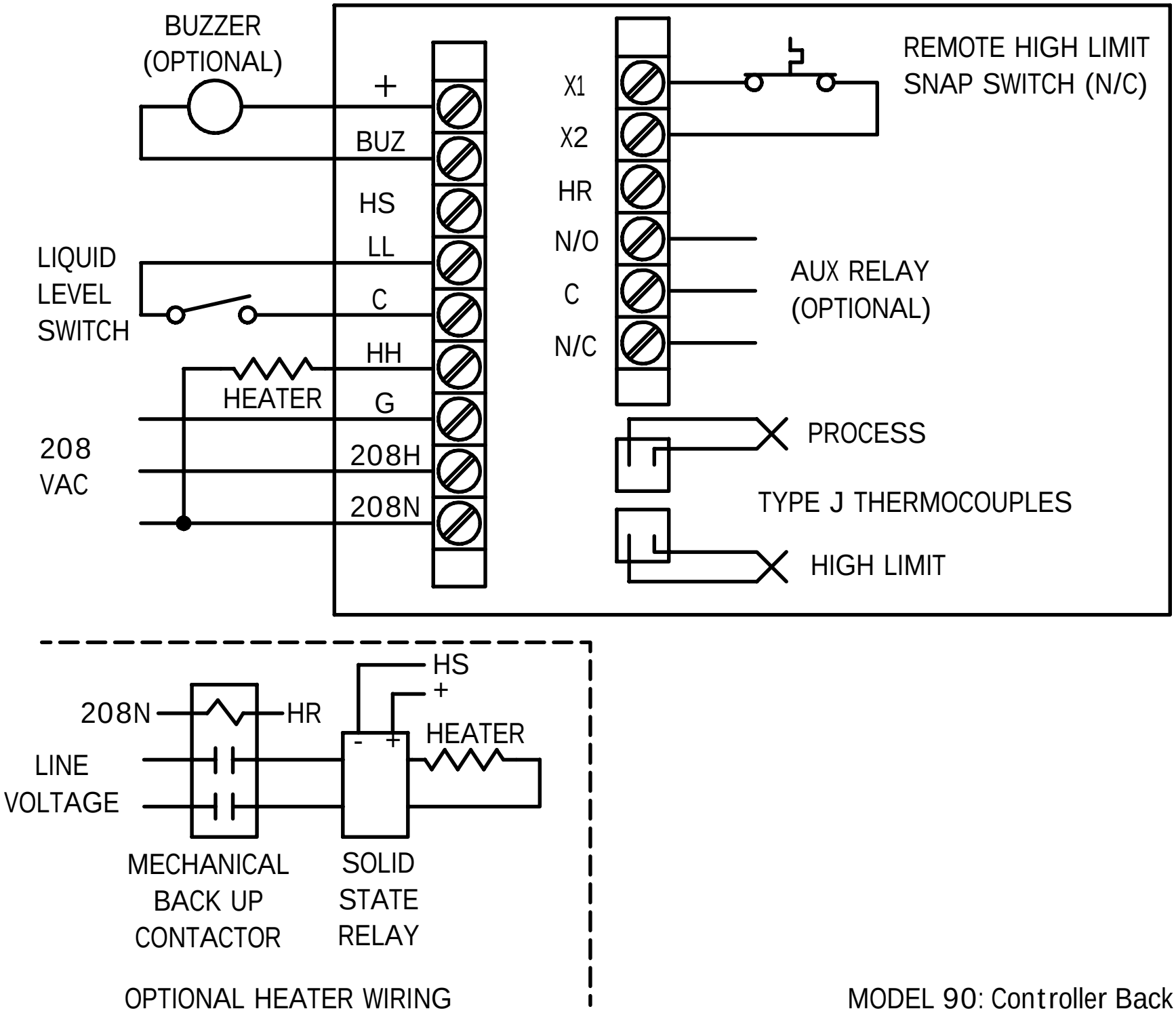
Backdoor Code

A special code has been incorporated into the software to ensure factory access to all functions—regardless what the customer has done with their access codes.

The Backdoor Code is 321.

System Specifications

Name	PCT Systems, Inc. Model 90: Constant Temperature Bath Controller
Temperature Range	0.0°–199.9°C
Temperature Resolution	0.1°C
Noise Rejection	NMR: -60dB @ 60Hz CMR: -120dB @ 60Hz
Time Range	0:00–99:59 (Minutes:Seconds)
Time Resolution	1 Second
Measuring Time	4 Conversions/Second
Display	8, 0.56” high, 7-segment, LED Uniplanar Numerals, 12 Discrete LEDs (Red, Green, Amber)
Annunciator	Audio Tone, ~2500 Hz
Setup Memory	EEPROM, All Parameters
Memory Retention	10 Years without Power
Sensor	Standard: Type-J Thermocouple, Cold Junction Compensation, Up Scale Break Protection
Control	PID with Anti-Reset Windup
Adjustment	Cycle Rate: 1–19 Seconds Proportional Band: 0.1°–19.9°C Reset (Integral): 0.1–19.9 Seconds Rate (Derivative): 0.1–19.9Seconds Calibration Offset: $\pm$9.9°C
Operating Range	0°C to 50°C
Storage Range	-40°C to 60°C
Construction	Enclosure: Kydex Face: Lexan, Back Printed
Size (H x W x D)	7” x 6” x 5.25” 178 mm x 152 mm x 133 mm
Weight	$\leq$ 4 pounds (1.8 kg)
Connection	Rear, Screw-Type, 3/8-inch Centers; Thermocouple: Miniature, Type-J, Jack
Output	SSR, Optically Isolated, Zero Cross, 20 Amp, 208 VAC
Power	11 VA, 208 VAC $\pm$10%, 50/60 Hz



OPTIONAL HEATER WIRING

MODEL 90: Controller Back Panel

Notes

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